LA-5459-SR

STATUS REPORT

171
1-21-74

Rapid Excavation by Rock Melting
-- LASL Subterrene Program --

December 31, 1972, to September 1, 1973

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

In the interest of prompt distribution, this Status Report was not edited by the Technical Information Staff.

Printed in the United States of America. Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $4.00. Microfiche $1.45

LA-5459-SR
Status Report
UC-38

ISSUED: November 1973

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

Rapid Excavation by Rock Melting

-- LASL Subterrene Program --

December 31, 1972, to September 1, 1973

Compiled by

R. J. Hanold

Work supported in part by a grant from the National Science Foundation, Research Applied to National Needs (NSF-RANN).

CONTENTS

Project Abstract iv

I. Introduction & Summary 1

A. Objectives 1

B. Technical Approach 1

C. Summary 1

II. Prototype Design and Test 5

A. Preliminary Design of Geoprospector 5

B. Penetrator Development 5

C. Alluvium Coring Penetrator Development 10

D. Glass Forming Tool Development 11

III. Directed Research and Development 12

A. Materials Science and Technology 12

B. Refractory Alloy Fabrication 14

C. Geosciences 14

IV. Power Source Design and Development 16

A. Electric Power Sources 16

B. Power Source Controls 19

V. Field Test and Demonstrations 20

A. Field Demonstration Units 20

B. Large Diameter, Mobile Test Rig 22

C. Tower Rig 22

D. Penetrator Life Test Facility 23

E. Test Site Location and Preparation 23

VI. Systems Analysis and Applications 24

A. Large Tunneler Design and System Definition Study 24

B. Theoretical Analysis 27

C. Systems Integration and Model Studies 30

D. Applications and Technology Utilization 31

VII. Technical Reports 33

A. Completed Technical Reports 33

B. Technical Reports in Progress 34

C. Presentations and Journal Articles 34

PROJECT ABSTRACT

Research is continuing on establishing the technical and economic feasibility of excavation systems based upon the rock-melting (Subterrene) concept. A series of electrically powered, small-diameter prototype melting penetrators have been developed and tested. Research activities include optimizing penetrator configurations, designing high-performance heater systems, and improving refractory-metals technology. The properties of the glass linings that are automatically formed on the melted holes are being investigated for a wide variety of rocks and soils. Thermal and fluid-mechanics analyses of the melt flows are being conducted with the objective of optimizing penetrator designs. Initial economic models of the rock-melting concept extended to large tunnelers are being developed. Field tests and demonstrations of the prototype devices continue to be performed in a wide range of rock and soil types. The conceptual design of the electrically powered, self-propelled, remotely guided, horizontal tunnel-alignment prospecting system (Geoprospector) has been initiated. Such a device will also find applications in energy transmission, i.e., utility and pipeline installations.

The long-term goal of the research is to develop the technology and prototype hardware that will ultimately lead to large tunneling devices, with improved advance rates and reduced tunnel project costs. The rock-melting concept includes elements that will result in innovative solutions to the three major functional areas of tunneling: rock disintegration, materials handling, and hole-support linings. The proposed excavation method, which is relatively insensitive to variations in rock formation, produces a liquid melt that can be chilled to a glass and formed into a dense, strong, firmly attached hole lining.

Unique applications to large automated tunneling systems, ultradeep coring for geoscience research, and hot-rock penetration for geothermal energy development are being investigated.

I. INTRODUCTION AND SUMMARY

A. Objectives

The technical efforts and resources of the LASL rock-melting (Subterrene) program have been distributed to yield a balance of prototype hardware of increasing complexity and size, laboratory experiments, practical field-test experience, design and economic analyses, electric heater development, materials development and applications, and theoretical studies. The results of these technical activities are planned to yield:

- The demonstration of the basic feasibility of rock-melting as a new excavation tool for applications up to 150 mm (6 in.) in diameter.
- Operational and field-test data from prototype devices of a range of sizes and configurations, and the verification of preliminary theoretical modeling needed to scale to larger diameters, predict performance, make cost estimates, and optimize advance rate and reliability.
- Refractory materials technology sufficiently established to permit predictions of component life and to generate materials selection criteria for prototype development needs and projections of service life for systems in practical applications.
- Field-test experience and operational demonstrations sufficient to project commercial use in the important practical application of coring in loose or unconsolidated materials, and to demonstrate the potential utility of the smaller-diameter prototype devices.
- Theoretical models and analytical techniques needed to describe the heat transfer and fluid mechanics of the rock-melting and penetration processes for the purposes of optimizing configurations, predicting performance, and scaling of system dimensions.

B. Technical Approach

The technical effort is organized into five technical activity areas whose functions are:

- Prototype Design and Test.
- Directed Research and Development.
- Power Source Design and Development
- Field Test and Demonstrations
- Systems Analysis and Applications.

The significant results and achievements in the research and development program are summarized for each of these five technical activities in five major sections of this report for the period December 31, 1972 to September 1, 1973.

C. Summary

The beginning of this year has seen a considerable expansion of the LASL research and development efforts in applying rock- and soil-melting techniques to excavation technology. Extended laboratory and field activities have been initiated. The technical staff assigned to the program and the laboratory facilities have been increased significantly. The Program staffing and technical tasks are planned to form the nucleus for an effort that would be directed toward the application of rock-melting to large-diameter tunneling systems.

The design and development of the initial configuration of an extruding penetrator was finished. Laboratory experiments with this 66-mm-diam, single-melt-flow-channel, extruding penetrator were successfully completed and holes were melted in basalts, granite, and a variety of low-density and loose soils. These universal extruding penetrators (UEPs) showed the basic features of rock-melt flow handling. Debris in the form of glass pellets, glass rods, or rock wool was formed by chilling the melt and carrying the debris out of the stem with the coolant flow. A larger-diameter (82 mm) high-advance-rate UEP was designed and fabricated. The 114-mm-diam coring-consolidating penetrator system that produces a 63-mm-diam, glass-cased core was designed, fabricated, and initially tested. The conceptual design study for a 300-mm-diam coring Geoprospector was finished. This electrically powered minitunneler is intended to be the major design study of the current program and is based upon the experience, data, analysis, and concepts developed by the prototype-penetrator design and development effort.

At the relatively high temperatures, 1600 to 2300 K, of rock-melting penetrator system operation, most materials react with one another to some extent and thermodynamic and kinetic lifetime limitations are therefore under investigation. Component and field data have confirmed a service life of $\sim$ 200 h. Materials research in the interaction of refractory metals with liquid rock melts thus far indicates that a life goal of 1000 h is possible. Techniques for rock-glass property evaluation and optimization are under development. The aim of the work is to perfect rock-melt glass as an _in situ_ structural element to serve as hole support in the excavation. Refractory materials fabrication techniques necessary for development purposes have been established. Thermal- and physical-property data sufficient for input to analyses have been acquired.

The design, materials selection, and testing of a wide variety of electrical heaters for small-diameter penetrators have been accomplished. Resistively heated, pyrolytic-graphite heater elements, which radiate energy to the refractory metal penetrator body, have proven to be most satisfactory for the development efforts. Increased advance-rate goals ($\sim$ 0.5 to 1.0 mm/s) require high-heat-flux heaters. Investigation of new designs and materials, heat pipes, and alternative approaches to resistance-heating have been initiated to enhance heater heat-flux capabilities. Life tests of heater assemblies have been initiated.

Field-test units for a small-diameter penetrator system were designed, fabricated, and operated. Evaluations of consolidating and extruding penetrator systems have provided valuable data and experience on reliability and service life. A practical application of melting glass-lined drainage holes in Indian ruins was demonstrated to visitors of the Bandelier National Monument, NM. Mobilization of field units for a public demonstration in Washington, DC, or at other locations has been completed. The design, specifications, and purchase of a mobile rig for large-diameter penetrators with 300-m stem-length capacity have been completed

Conceptual designs of large-diameter tunnel-boring machines were established for the extremes of the difficult tunneling conditions of unconsolidated ground and very hard abrasive rocks. A benefit-to-cost

study was completed and indicated that savings on projected transportation demands through 1990 were sufficient to give a benefit/cost ratio of 8.5 for a development cost of $\$100 \times 10^6$. Theoretical analyses of the heat transfer, of the melting processes, and of the fluid mechanics of melt-flow are well advanced. Numerical solutions of the coupled melt-flow and energy relations, accounting for the strong temperature dependence of rock-melt viscosity, and studies of a variety of penetrator geometries have been accomplished. These theoretical studies give direction toward penetrator designs which will maximize the advance rate and minimize thrust requirements. Optimizations of configurations for both consolidating and extruding penetrators have been performed. Significant operating maps for past and current penetrator designs have been developed. Confirmation by laboratory operating data for some penetrators have established the validity of those analyses. Therefore, a detailed predictive method for the melting concepts has been perfected, and design and scaling to large-diameter tunnelers can now be accomplished reliably. Computer programs for thermal conduction and structural analyses have been developed.

The study of applications of Subterrene systems to a wide variety of excavation tasks continued. Particular interest in a small-diameter system for forming glass-lined horizontal holes for utility emplacement and drainage applications motivated a preliminary design of such a system. The Geoprospector concept, especially the self-propulsion and remote-guidance features, continues to elicit interested responses from the excavation industry. Pipeline installation and the placing of transmission lines underground are major application areas. The melting of holes in permafrost for support pilings of arctic oil and gas pipelines have been discussed extensively with interested industrial firms.

The work conducted during this reporting period has clearly delineated the design directions and solution approaches needed to solve the major outstanding technical problems: increased penetration rate and extended service life.

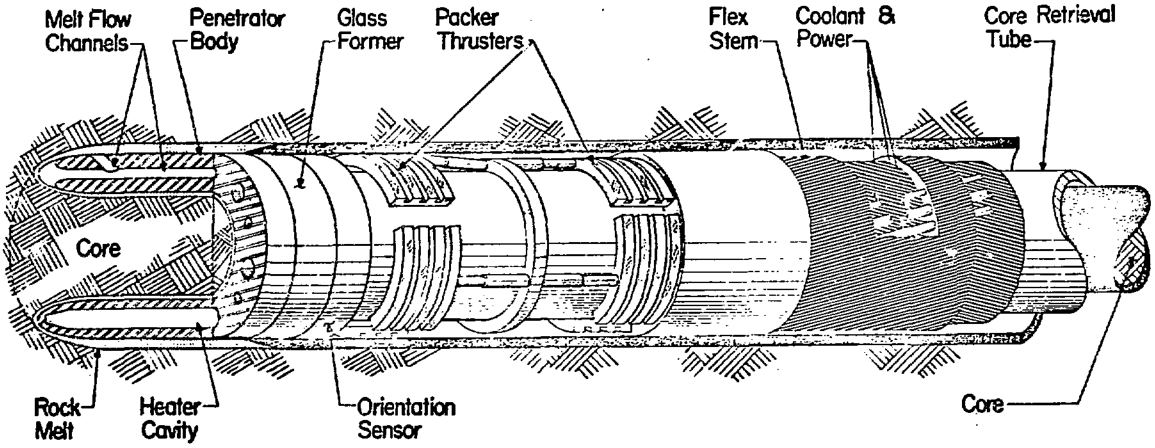


Fig. 1. Geoprospector conceptual design.

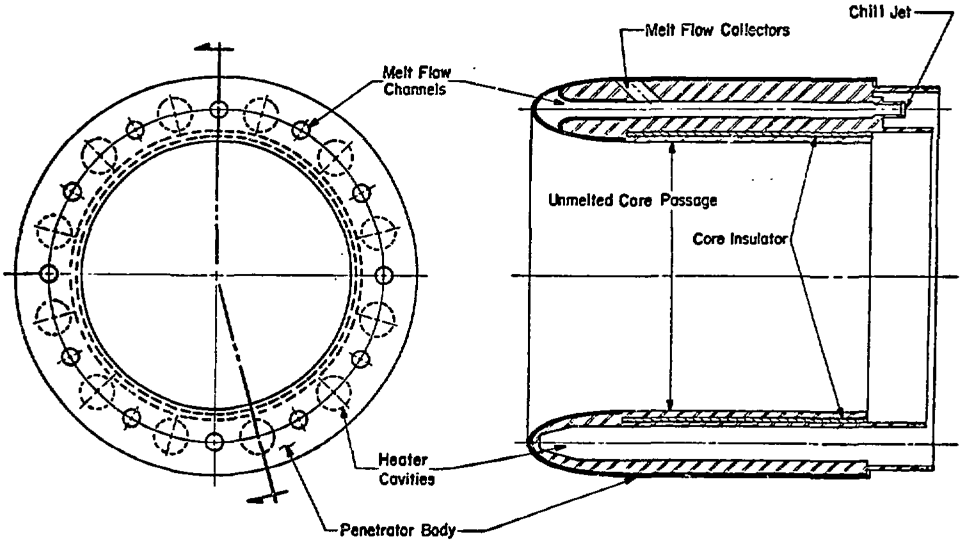


Fig. 2. Penetrator body and melting-surface configuration.

A. Preliminary Design of Geoprospector

1. Introduction

A Subterrene system with immediate applications would be a relatively small-diameter (300 mm), electrically powered minitunneler that would be remotely guided and self-propelled to form a hole along a proposed tunnel route while continuously extracting core samples. Such a system would enable detailed analyses to be made of the geology along a proposed tunnel route. This system, termed a Geoprospector, is intended to perform this survey task and additionally to serve as a small-scale prototype in anticipation of some problems that will arise in the future development of larger-diameter nuclear-powered Subterrene tunnelers.

2. Conceptual Design

The conceptual design of the Geoprospector is well advanced and the general design features of the system are illustrated by the isometric sketch in Fig. 1. The device is electrically powered, requires ~ 100 kW of power to melt an accurate 300-mm (1-ft)-diam glass-lined hole while removing a 200-mm (8-in.) glass-cased core at a rate of 0.4 mm/s (5 ft/h). The accurate diameter and stable hole lining allow the use of a packer-thruster unit located in the hole-forming assembly. Provision is made for an orientation-sensor package and a guidance unit, also located within the hole-forming assembly. A hollow, flexible stem which trails behind the assembly contains the electric power, coolant, and instrumentation lines; and provides a debris passage for removal of the chilled melt. Core sections are removed through the flexible stem intermittently with conventional wire-line core retrieval hardware.

3. Penetrator Body, Glass Forming, and Debris Removal

The configuration of the penetrator body and melting surface is shown in Fig. 2. The melting face is envisaged to have 12 axial channels through which rock melt flows to the chill-jet nozzles. The penetrator body is designed to operate at a surface temperature of 1870 K and will be fabricated from molybdenum-tungsten alloy either forged in a continuous-ring rolled shape or assembled from 12 separate modular units. Auxilliary melt-flow channels will be provided adjacent to the melting surface to enhance the effectiveness of the melt-removal process by directing melted rock into the channels leading to the chill-jet nozzles. Except for the factors governed by the relatively large assembled size of the penetrator, the technology necessary to build and operate the penetrator body and melting surface is being tested as part of the current Subterrene rock-melting technical activities.

Two distinct heater design options are available for the Geoprospector concept. In the first, the heaters would be located in the penetrator body in a circumferential pattern, and radiation heat transfer would be utilized to deposit the required melting energy into the refractory metal melting surfaces. The second design would locate the heater farther away from the melting surface and would couple the thermal energy to this surface through a series of high-temperature, liquid-metal heat pipes. The relative advantages of the two heater-system options are being critically examined.

The major functions of the rock-glass forming and debris-removal system are (1) to form a dense structural glass lining on the wall of the hole and (2) to duct the melted rock from the annular melting face through an array of melt-chilling jets where the scoria will mix with a coolant fluid, be frozen into particles, and then be removed by fluid transport via the flex stem. These functions are illustrated in Fig. 3.

B. Penetrator Development

1. Consolidation Penetrator Experiments

Penetration by melting and subsequent density consolidation relies upon the porosity of the parent

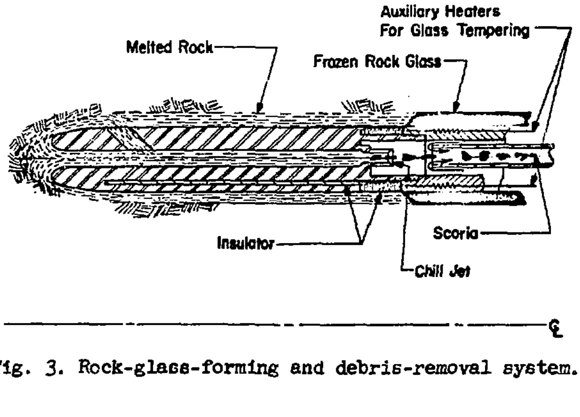


Fig. 3. Rock-glass-forming and debris-removal system.

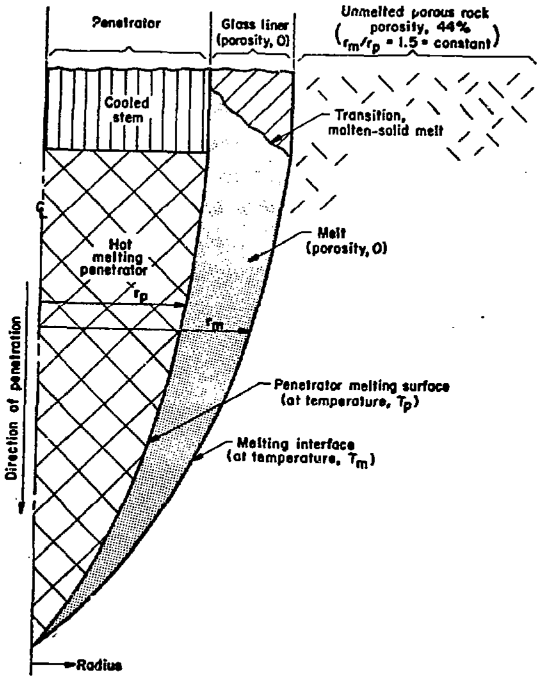


Fig. 4. Schematic of density consolidation in porous rock.

rock or soil. This process is illustrated in Fig. 4, which shows how the rock melt is formed into a glass lining and how the larger hole diameter is melted to accommodate the lining

This method of penetration eliminates the debris-removal process. The ratio of outer to inner radius of the glass lining is therefore related to the properties of the rock and lining by the conservation of mass. The resulting radius ratio is:

$$\frac{r_m}{r_p} = \sqrt{\frac{1}{1 - \frac{\rho_R}{\rho_L}}}$$

where r_m is the outer radius of the glass lining, r_p is the radius of the penetrator or inner glass lining, ρ_R is the density of unmelted rock, and ρ_L is the density of the glass lining. Penetrators utilizing density consolidation for melt disposal are referred to as melting-consolidating penetrators (MCPs).

Significant technical achievements in this area include:

- Consolidation penetrator designs have been developed to the point where compressed-air-cooled, oxidation-resistant, easily replaceable penetrators are in satisfactory use for both laboratory experiments and field demonstrations.
- A 75-mm (3.0-in.)-diam MCP has been designed, constructed, and laboratory tested. At heater powers of ≈ 6.1 kW and thrust loads of 2.5 to 7.5 kN, advance rates up to 0.15 mm/s were obtained. The glass linings of the holes were of the predicted thickness and the higher thrust loads resulted in smooth, high-strength glass linings of lower porosity.
- A small, 12-mm-diam desk-top penetrator was designed and tested successfully. Several units were produced and used in demonstrations of the melting process.
- The design of a revised 75-mm-diam penetrator system has been completed to initiate investigations of steering and guidance methods by a series of experiments in making horizontal holes.
- A series of tests were carried out with the 75-mm-diam MCP melting into specimens of tuff and alluvium to obtain performance data on the variation of penetration rate with thrust load. These tests generated significant data, indicating that higher thrust loads (in alluvium particularly) are beneficial in obtaining higher advance rates.
- A test was performed in which the tuff specimen was tilted deliberately while being penetrated by the 75-mm-diam consolidating penetrator thus simulating a guided penetrator in which steering is accomplished by stem-warping. The test demonstrated that a path deviation of 1.5 degrees per 80 mm of advance is feasible (radius of curvature, ≈ 4 m).
- The design of a 50-mm-diam penetrator with a fluted body was completed, which should have some structural and melt-flow advantages over a conventional configuration.

2. Extrusion Experiments in Hard, Dense Rock

Extrusion penetrators are required in dense materials and are designed to continuously remove the debris from the bore hole. As indicated in Fig. 5 the melt flow, confined by the unmelted rock and the hot melting face of the penetrator, is continuously extruded through a hole (or holes) in the melting face. This material is chilled and freezes shortly after the circulating cooling fluid impinges upon the extrudate exiting from the extrusion region.

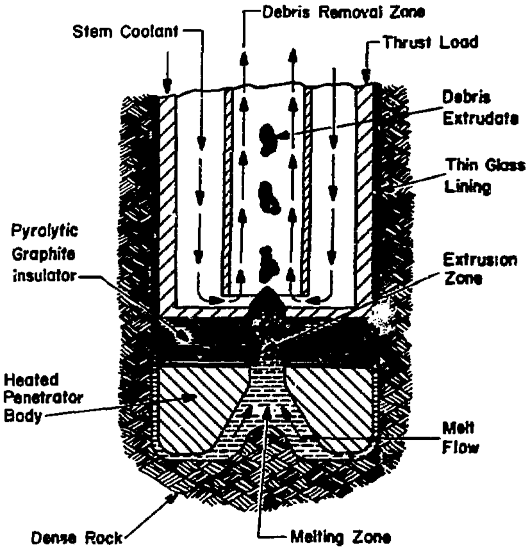


Fig. 5. Extruding penetrator concept.

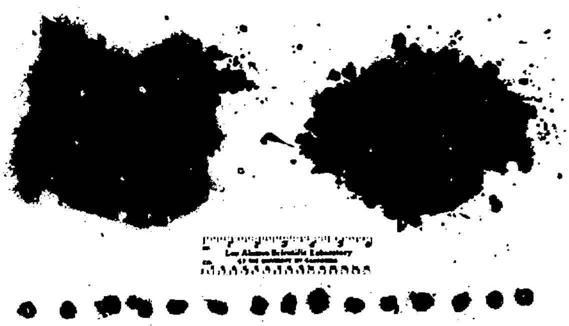


Fig. 6. Debris from basalt hole made by extruding penetrator showing rock wool and glass-pellet constituents.

If freezing is accomplished quickly, the material will be in the form of frozen glass rods, pellets, or rock wool. The flowing coolant can then transport these small fragments up the stem to the exhaust section. Typical pellets and rock wool that were formed from frozen extrudate and removed by the cooling fluid during a basalt test are shown in Fig. 6.

Significant technical achievements in this area include:

- Extruding penetrators have been used successfully to produce glass-lined bores in samples of tuff, alluvium, basalt, and granite. In view of their demonstrated versatility in varying rock and ground types, they will be referred to as "Universal Extruding Penetrators" (UEPs).

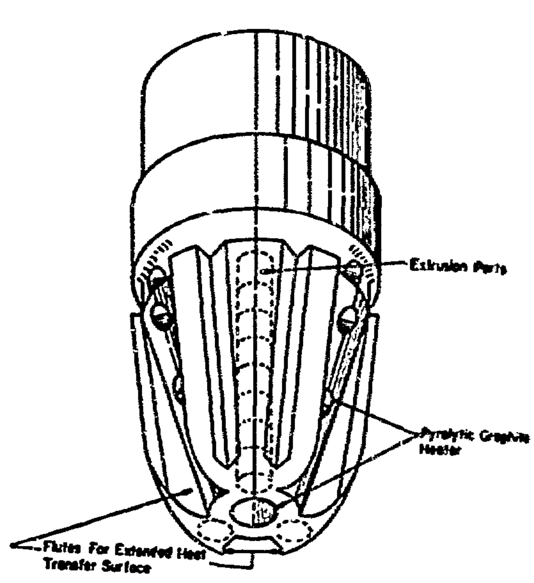


Fig. 7. Extended-surface 82-mm-diam UEP.

- A 66-mm-diam UEP was assembled and tests were initiated. A series of laboratory melting and endurance tests were conducted in preparation for field tests in a basalt ledge.
- A 65-mm-diam extrusion penetrator melted a hole in a concrete specimen.
- The design of a UEP with a higher advance rate was completed and fabrication has commenced. The design required a diameter of 82 mm to accommodate the requisite melt-flow channels and three sets of pyrolytic-graphite heater stacks. This design introduces the concepts of extended melting surfaces and multiple melt-removal or -transfer channels to promote thinner melt layers. A sketch of this penetrator is shown in Fig. 7, and the predicted performance map for this penetrator melting in basalt is included as Fig. 8.

3. Experiments in Diversified Rock Types

The ability of MCPs to produce smooth, strong, firmly attached glass linings in a variety of consolidated or unconsolidated low-density rocks and soils has been continually demonstrated since the

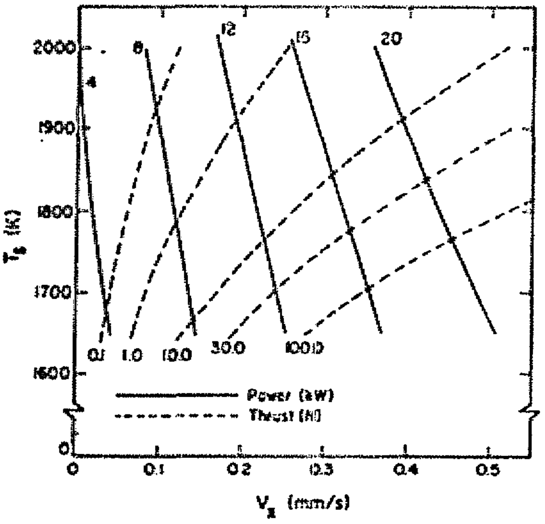


Fig. 8. Projected lithothermodynamic performance for 82-mm-diam high-advance-rate UEP in basalt. Penetration rate, V_x, vs penetrator surface temperature, T_s, showing curves of constant power and thrust.

Fig. 10. Exterior view of self-supporting glass-lined hole melted in unconsolidated alluvium.

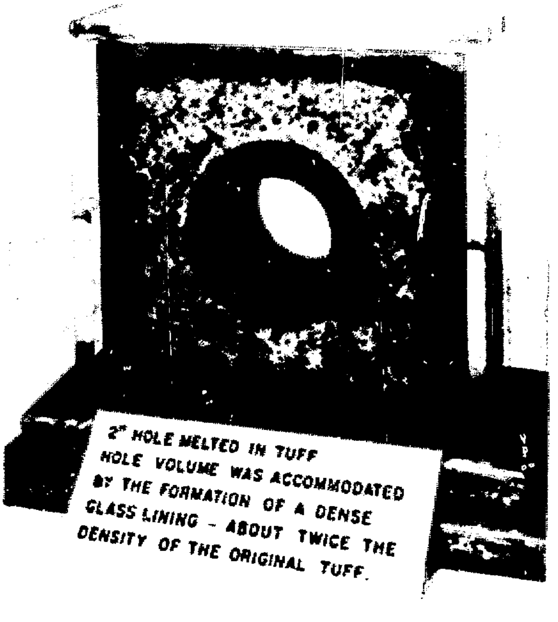


Fig. 9. Cross section of hole melted in tuff.

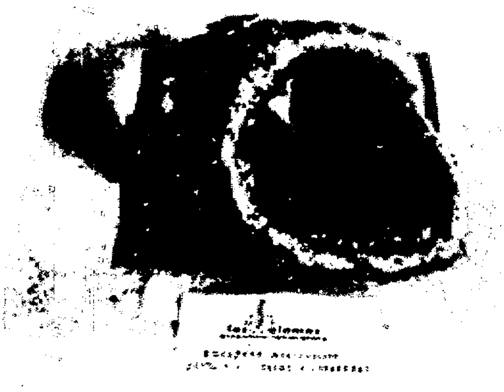


Fig. 11. Sample of glass-lined bore melted in simulated artic permafrost.

Fig. 12. Hole in granite sample melted by UEP. Note extruded debris and thin glass lining.

inception of the program. Typical examples are the thick glass lining associated with a hole melted in tuff illustrated in Fig. 9 and a self-supporting glass-lined hole melted in unconsolidated alluvium illustrated in Fig. 10. A more novel application involves a series of tests using 50- and 75-mm-diam MCPs melting into frozen (200 K) alluvial specimens containing ~ 16-20% water by weight (simulated arctic permafrost). The penetrators readily produced glass-lined holes in the frozen specimens as depicted in Fig. 11.

In hard, dense rock, UEPs incorporating coaxial-jet debris-removal systems have successfully penetrated and glass-lined bores in basalt and granite, with the granite hole and debris illustrated in Fig. 12 representing a typical sample. Experiments have also been carried out with the UEPs melting in porous materials such as tuff. The tuff extrudate consisted of glass rods that broke off only when the rod extended the length of the experimental stem. The differences between the basalt and tuff extrudate are ascribed to the large difference in viscosity between the two glass melts and to the significant volume fraction of unmelted quartz crystals in the tuff melt. The UEP produced a thin glass lining on the hole, in contrast to the thicker linings formed in tuff by MCPs. The thin glass lining and extruded glass rods are illustrated in Fig. 13.

To provide further standardization in rock-melting penetration tests, a set of eight standard rock types commonly used in rock mechanics research has been ordered. This set includes basalt, granite (3 types), limestone (2 types), quartzite, and sandstone.

Fig. 13. Hole in tuff melted by UEP. Note rods of extrudate and thin glass hole lining.

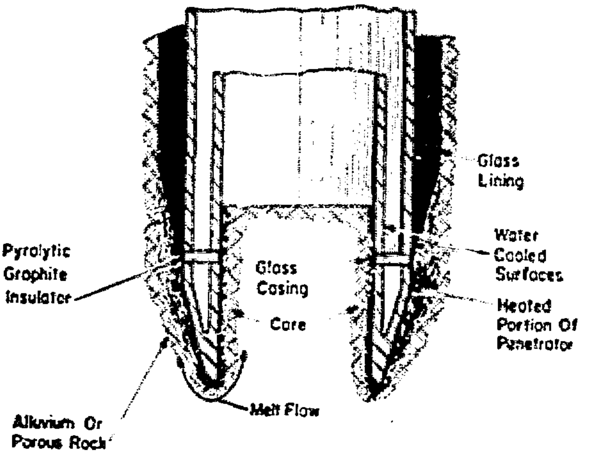


Fig. 14. Schematic of consolidating-coring penetrator.

4. High Advance Rate Experiments

As indicated in Section II-B, design has been completed and fabrication started of an 82-mm-diam extrusion penetrator having a large surface heat-transfer area, multiple melt-flow passages, and multiple heater stacks. Based on the enhanced surface area, reduced operating melt layer thickness, and high thrust capability, analyses predict that this unit will melt rock at a significantly faster ($\sim 3\times$) rate than previous UEP designs. A design study has also been initiated on a high-advance-rate consolidating penetrator that will incorporate the favorable aspects of the melt-transfer consolidation (MTC) concept detected by analytical studies. The theoretical analysis of this concept is covered in detail in Section VI-B. Advance-rate goals of from 0.4 to 0.8 mm/s ($\sim$ 5 to 10 ft/h) have been chosen.

C. Alluvium Coring Penetrator Development

The Subterrene concept of rock penetration by progressive melting has been expanded to include a technique for obtaining continuously retrievable geologically interesting core samples from the material being penetrated. The coring concept utilizes an annular melting penetrator which leaves an unmelted core in the interior that can be removed by conventional core-retrieval techniques. Although the concept is applicable to either the extrusion or consolidation mode of melt-handling, initial emphasis has been placed on a consolidating-coring penetrator as illustrated schematically in Fig. 14.

A 114-mm-diam consolidating corer intended for use in porous alluvial soils has been designed, constructed, and calibration-tested in the laboratory. The core diameter is 64 mm and the melting body, which is vacuum-arc-cast molybdenum, is fabricated as a single-structural component as illustrated in Fig. 15. The water cooling system incorporated represents a departure from the conventional gas systems and has been successfully checked in the laboratory. Minor adaptations of commercially available core extraction tools are in progress for use with the alluvium corer. Design power level is 13 kW, and initial testing was accomplished at 9 kW in alluvium with low thrust loads and penetration rates in

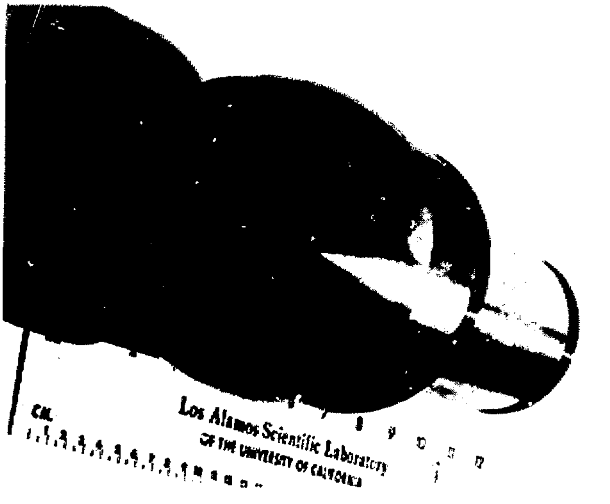


Fig. 15. Photograph of 114-mm-diameter consolidating-coring penetrator.

the range from 0.05 to 0.15 mm/s. Initial testing supported by two-dimensional heat-conduction calculations verified that rock-melt temperatures were undesirably high behind the insulating pyrolytic-graphite washer, resulting in high stem temperatures. This portion of the coring penetrator is being redesigned to alter the thermal fluxes, and further testing will commence after these design changes are implemented. A detailed litho-thermodynamic analysis of the performance of this design has been developed and directions for significant improvements in advance rate have been indicated.

D. Glass Forming Tool Development

Consolidation penetrators have been tested with high thrust loads into tuff specimens, and the glass walls of the resulting holes have been of much better visual quality than noted previously. It is postulated that the higher thrust loads and associated higher pressures in the rock melt minimize gas-bubble evolution which can cause voids in the glass walls. Theoretical calculations of thermal histories for glass linings have been initiated. These thermal histories follow the radial temperature profiles through the glass thickness and indicate the time spent by the freezing melt in the softening regime, working range, and annealing range of temperatures. Studies of the relative influence of cooling by the surrounding rock and the cooled stem will be used to assess the history of radial gradients in the glass wall and will therefore indicate residual stress/strain states. These time-history studies have yielded results which indicate the design directions for optimization of the thermal design of the glass-forming afterbodies of penetrator systems.

A. Materials Science and Technology

1. Introduction

The high temperatures reached in Subterrene penetrator systems require a set of materials maintaining not only structural and physical integrity, but also a high degree of chemical inertness over extended periods of time. Realization of this ideal situation becomes difficult at the suggested operating temperatures of the system, 1600 to 2300 K, and possibly higher in the case of certain radiant heater designs. The material temperature range is wide because a high power density must be transmitted from a central core of the heater so that ample heat flux can be conducted to the surface in contact with the rock. Because most materials will react with one another to some degree in this temperature range, intrinsic thermodynamic and kinetic lifetime limitations must be investigated.

2. Refractory Alloy-Rock Melt Interactions

A literature survey was conducted on the types of apparatus suitable for determining interaction rates between penetrator refractory alloys and rock melts. Although dynamic testing systems will eventually prove desirable, intentions are to initially use static compatability tests between molybdenum and tungsten and various rock melts. Static compatibility testing has been initiated with studies of the corrosion or dissolution reactions of molybdenum with standardized basalt rock. Figure 16 shows a typical penetrator coated with basalt glass after completion of a laboratory test. In these experiments the rock "standard" is melted in a molybdenum crucible and held at temperature for known periods of time. After cooling, the amount of metal dissolved in the rock glass is measured and the sectioned crucible is examined metallurgically for evidences of corrosion and chemical reactions. Prior to the actual test, the standardized rock is powered and a sample submitted for chemical analyses. The crucibles are likewise characterized with regard to chemical purity and pretest microstructure.

The first experiments, run at temperatures of 1528, 1913, and 1898 K are being analyzed. These experiments will investigate quantitatively the effects of time and temperature on the reactions between molybdenum and rock glass melts. Information on reaction rates will be obtained, as well as on activation energies, equilibrium solubilities, and reaction mechanisms.

Compatibility experiments have been run between titanium and vanadium on the one hand, and basalt and tuff on the other. The objective was to determine a suitable brazing material for use at the aft end of penetrator bodies. At 1675 K the titanium was severely attacked, whereas reactions with the vanadium were much less severe suggesting its use as a brazing material.

Postmortem metallurgical examinations of several molybdenum penetrators (including a unit field-tested under especially harsh conditions for 295 ks = 82 h) are in progress. Both a pretest and a post-test molybdenum penetrator have been examined by x-ray radiography. The pretest "shadowgraph" will be used as a basis for nondestructive examination after long-term operations. Radiographs of the used unit showed that corrosion can be observed by this technique and

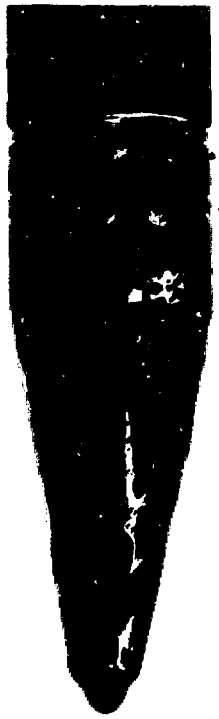


Fig. 16. Penetrator coated with basalt glass after withdrawal from hole.

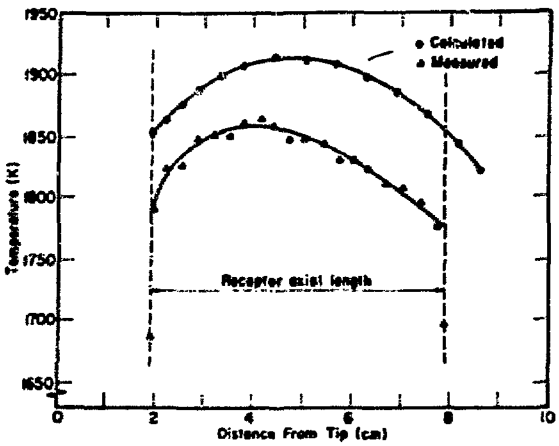


Fig. 17. Comparison of calculated and experimentally indicated penetrator temperatures at the graphite receptor - molybdenum body interface.

that the state of the graphite heater pills inside may also be seen.

3. Power Source Materials

The basic chemical reactions involved in Subterrene power-source materials are those of the refractory metal-carbon system, with some possible contributions from impurities within the metal, carbon, and helium gas that surrounds the heater. The motivating reason for studying these chemical reactions is the possibility of predicting and enhancing penetrator lifetime, a most important economic factor. The lifetime of a penetrator unit must be ultimately dependent upon the internal refractory metal-graphite interactions for the prototype radiant-heater penetrators currently being used.

Significant technical achievements in this area include:

- Internal chemical reactivity in prototype Subterrene radiant-heater penetrators has been investigated by means of sectioning and examining metallurgical samples. Dimolybdenum carbide, Mo_2C, is the major reaction product formed between the base metal and the graphite receptor interface. In those regions where carbiding has occurred, temperatures have been computed by means of measurement of the carbide layer thickness and the use of reaction-rate data for the Mo-C system. These temperatures have been compared to those calculated from thermal-analysis considerations. As illustrated in Fig. 17, agreement is very good, with the calculated values being ~ 50 K higher. The comparison is limited to those regions where the carbide layer has not delaminated internally.
- The present radiant-heater design is considered superior to that using the molybdenum/boron-nitride/carbon set of materials in view of a marked reduction in complexity and number of potential chemical reactions. Higher operating temperatures are also possible.
- Similar experimental techniques should be applicable to penetrators fabricated from other refractory metal-carbon systems for which appropriate reaction-rate data are available.
- Using available molybdenum-graphite reaction-rate data, the graphite receptor thickness required for a 1000-h lifetime at a given temperature has been calculated. The results for a thin-walled cylindrical receptor and a plane receptor are shown in Fig. 18. Note that these data are strongly temperature-dependent. By using the activitation energies it can be shown that a temperature increase in the receptor of 200-300 K will increase the carbiding rate constant by a factor of ten and hence reduce the life by a corresponding factor. These calculations are being extended to the case of tungsten penetrator bodies and TaC-coated receptors.
- Preliminary experiments have been initiated to evaluate thin vapor-deposited TaC coatings on graphite receptors to serve as a barrier in preventing excessive internal carbiding within the molybdenum penetrator body. Graphite receptors and electrical contact rods have been coated with a layer of TaC having an average thickness of 0.33 mm. Initial results indicate that the diffusion barrier will be useful in extending receptor life, particularly for molybdenum penetrators.
- Additional internal oxidation protection for molybdenum extraction portions of penetrators has been provided through the use of either platinum or $MoSi_2$ coatings.

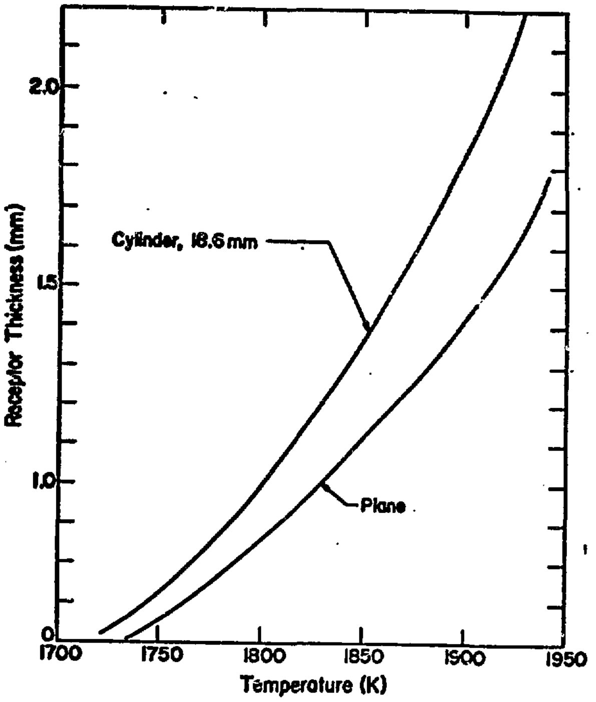


Fig. 18. Calculated graphite receptor thickness required for 1000 h life vs temperature for thin-walled cylinder and plane geometries.

- Penetrator service life goals of 1000 h have been established, and efforts are in progress to define life-limiting mechanisms and to indicate directions for solutions.

4. Rock Glass Technology

The Corning Glass Works, Corning, New York, were visited to acquire technical information about glass technology that can be applied to rock glasses and thereby form the basis for a rock-glass optimization development program. In addition, the groundwork was established for technical collaboration with Corning in the Subterrene program relative to such tasks as rock-melt viscosity determinations. As a result of this visit, a rock-glass development and strength-optimization program has been outlined and initiated.

B. Refractory Alloy Fabrication

The majority of penetrators thus far have been fabricated from molybdenum. The several tungsten penetrators that have been fabricated and tested have clearly demonstrated that tungsten has the capability of operating at higher temperatures and hence yielding greater penetration rates. An extensive effort has been initiated to ensure acquisition of tungsten stock in the proper sizes and shapes for forthcoming Subterrene penetrator fabrication. General Electric Co., Cleveland, OH, can produce tungsten blanks as large as 200 mm in diameter, and Wah Chang Corp., Albany, OR, is optimistic about working in large forged and ring-rolled shapes of tungsten and moly-tungsten alloys. The fabrication technology required to pierce and ring-roll large tungsten shapes is not expected to introduce any particularly new problems.

A new alloy, Mo-30 wt% W, has been obtained and is undergoing metallurgical examination. Consolidating 50-mm-diam penetrators have been fabricated from this alloy, and manufacturing ease was found to be equivalent to that of molybdenum even though the alloy has a melting temperature 100 K higher.

Refractory-metal machining techniques have advanced to the stage where large, fluted, profiled bodies are being fabricated and deep holes are being drilled in molybdenum parts. In addition, techniques have been developed for high-temperature (2000-2300 K) vacuum furnace-brazing of penetrator components.

C. Geosciences

Significant technical achievements in this area include:

- A literature search was conducted to locate the general rheological and thermal properties of basalt melts. A report compiling these properties for basalt has been prepared.
- Preliminary planning for petrological examination of parent rock and derived rock-glass samples is in progress. The potential correlation of petrographic information with physical properties and ultimately its extension to Subterrene design and performance are the desired goals.
- Melting tests have been conducted on several samples of concrete, in particular those used in the 66-mm-diam UEP test. Results indicate that this grade of concrete melts in the vicinity of 1525-1575 K and should be capable of extrusion. Not all components melt, however, but this problem also exists in tuff which has been extruded successfully.
- The melting behavior of granitic gneiss samples has been determined. These samples

were obtained from a quarry on the grounds of Ft. Belvoir, VA, the site chosen for the Washington, DC, display and demonstration.

- Compatibility experiments between molybdenum, tungsten, and basement granites obtained from a borehole made in conjunction with the Geothermal Energy program have been completed.
- A diamond coring setup to obtain small samples of rocks and glasses has been completed. Cores may range up to 25 mm in length and from ~ 3 to 25 mm in diameter. This setup coupled with the Isomet saw and a diamond wire cutter will provide precision-sampling capability.
- Melting-range experiments have been completed on Nevada Test Site alluvial soil, NV; Tuzigoot National Monument, AZ; and Pecos National Monument, NM, rock samples.
- A precision air pycnometer has been added to the laboratory rock-diagnostic equipment. Coupled with adequate sample preparation and weight measurement, it will be possible to accurately determine the density, bulk density, and degree of porosity of the various rocks and minerals.
- Analysis of the total free silica in Bandelier tuff to a depth of 38 m has been completed. The average free SiO_2 content is 30.8 ± 1.8%, including cristobalite, with a gradual but distinct trend towards higher SiO_2 content with increasing depth. These data supplement the chemical, mineralogical, and water-content information already obtained.

A. Electric Power Sources

1. Introduction

A wide variety of electrical heaters for small-diameter Subterrene penetrators have been designed, constructed, and tested. The basic materials problem is the incompatibility of refractory materials at the required operating temperatures of ~ 2000 to 2400 K, while the basic design problem stems from the requirement for large heat fluxes from the heater surfaces. These high fluxes are necessary to maintain the outer surfaces of the penetrators at operating temperatures high enough to melt rock at useful rates. Thermal resistances of materials required for electrical insulation must be kept low to reduce internal temperature gradients, because large gradients would require increased heater temperatures which, in turn, would accelerate the chemical reaction rates between the heater surfaces and adjacent materials.

The successful use of pyrolytic graphite as a radiant heating element and the low thermal resistance of a polycrystalline (POCO) graphite radiation receptor were combined to produce a very stable heater assembly. The heater consists of a stack of oriented pyrolytic-graphite disks held in a graphite-lined cavity by a spring-loaded graphite electrode. A cross-sectional view of a typical assembly is shown in Fig. 19.

The direct-current path is down the center stem conductor, through the spring-loaded electrode connector to the graphite electrode, down the electrode to the pyrolytic-graphite heater stack, through this stack to the molybdenum penetrator body, back up the body to the withdrawal structure, and through this structure to the afterbody and outer stem. The center conductor is made positive with respect to the outer stem to suppress thermal electron emission from the stack, thereby reducing the tendency for arcing between the heater stack and the receptor. The heater cavity is filled with helium to enhance the radial heat transfer. Heat fluxes of up to 2 MW/m^2 have been obtained from pyrolytic-graphite radiant-heater elements. The features of this design which contribute to efficiency and durability can be summarized as follows:

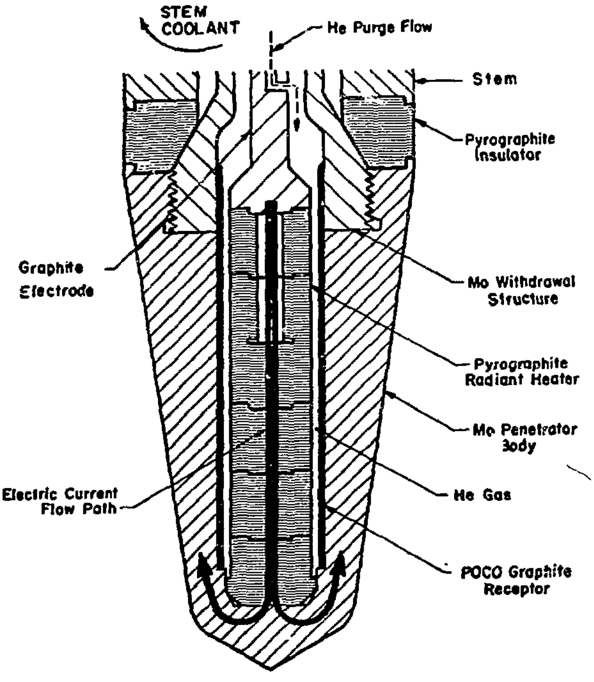


Fig. 19. Cross section of a consolidating penetrator with stacked pyrographite radiant heater and a POCO graphite radiation receptor.

- A heater cavity containing only graphite in the high-temperature region.
- The use of a specialty graphite (POCO) for the receptor whose thermal expansion characteristics match those of molybdenum and whose absorbtivity for radiation energy is near unity.
- A nonisotropic pyrolytic-graphite heater stack oriented so that the high electrical resistivity ("c" direction) is parallel to the penetrator axis, and the high thermal conductivity ("a-b" direction) is normal to the penetrator axis and in the direction of principal heat transfer.
- A hollow heater cavity to allow control of the relative heat generation along the penetrator length.
- Utilization of the exceptional combination of high compressive strength and low thermal conductivity of pyrolytic graphite ("c" direction) for the insulator between the heated penetrator body and the cooled afterbody.

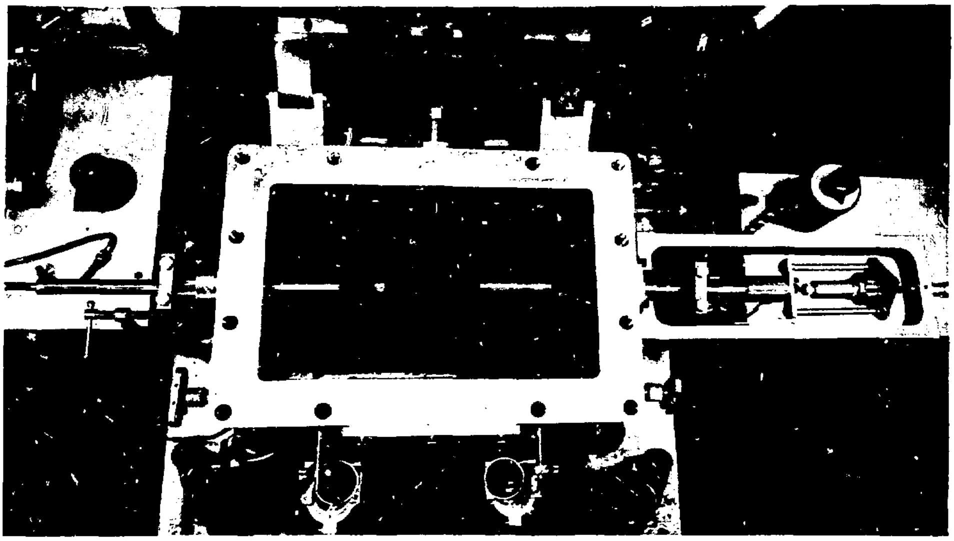


Fig. 20. Photograph of heater characterization apparatus.

2. Heater Development and Characteristics for Penetrator Research

Significant technical achievements in this area include:

- The design, fabrication, and field-testing of an improved electric heater for consolidation-mode penetrators (in which the penetrator body, withdrawal structure, heater elements, and graphite electrode are a hermetically sealed unit) was completed. Included in this development program was the fabrication of a special heater-processing apparatus for filling the penetrator with helium and testing the hermetic seal at operating temperatures. This apparatus is installed in the heater-development laboratory and is also used for temperature-cycling the completed penetrator system by using the internal heater.
- The design, fabrication, and utilization of a heater-characterization apparatus has been completed. Characterizations of pryolytic-graphite heater assemblies to be used in 50-mm MCPs, 66-mm UEPs, and 114-mm ACPs with respect to overall electrical resistance, specific resistivity, and heating uniformity at temperatures up to 2600 K were accomplished. A photograph of the heater-characterization apparatus is shown in Fig. 20, and typical resistance-vs-temperature plots for stacked pryolytic-graphite heaters obtained from this apparatus are shown in Fig. 21. Each heater element that will be used in a field or laboratory test penetrator is routinely characterized in this apparatus to verify heater uniformity and quality control.
- The design, fabrication, and utilization of the first heater test apparatus has been completed. The heater test apparatus evaluates heater performance under realistic conditions, but in a carefully instrumented situation and without the presence of molten rock. Various heater designs can be tested for performance in terms of operating temperature, input power, and heat-flux distributions as well as for electrical and chemical stability. A photograph of the apparatus taken during the initial assembly is shown in Fig. 22. The apparatus basically consists of: (1) a 50-mm-diam molybdenum cylinder which is analagous to a penetrator body, (2) a heater element identical to that used in the 50-mm MCP; (3) a closely fitted water-cooled copper jacket that acts as a heat sink for the energy rejected by the molybdenum cylinder, and (4) the associated instrumentation for monitoring the test.

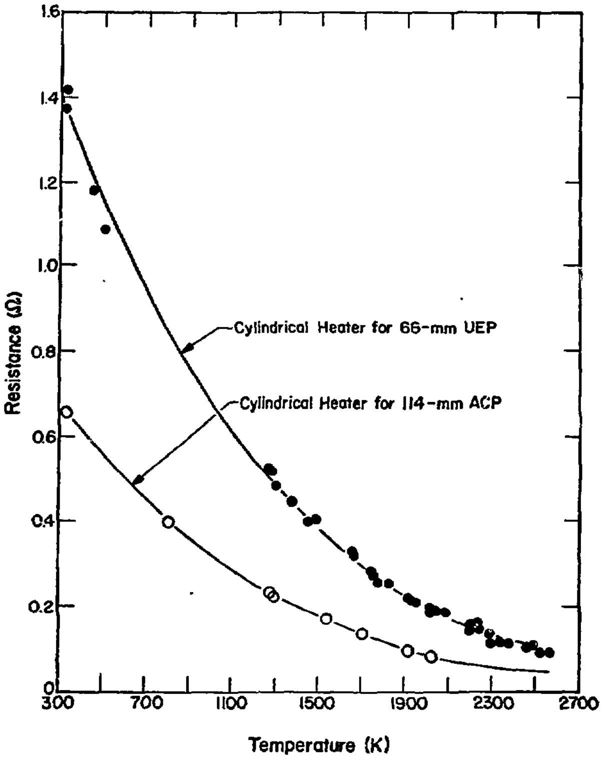


Fig. 21. Typical resistance-vs-temperature plots for pyrolytic-graphite heaters.

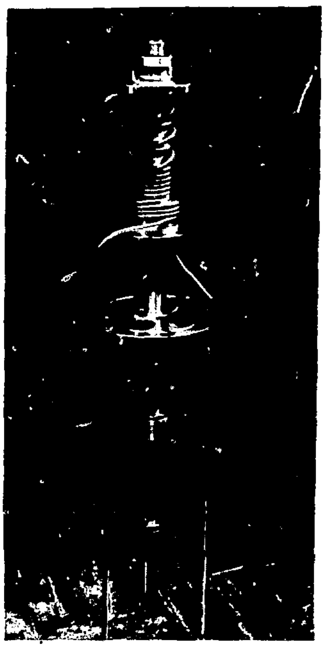


Fig. 22. Initial assembly of heater test apparatus.

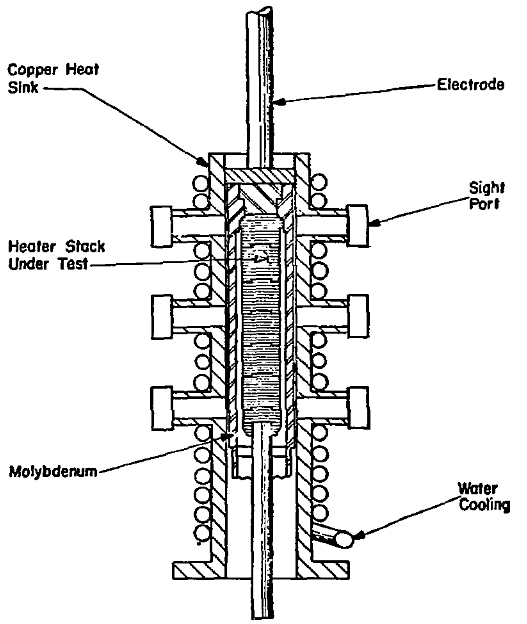


Fig. 23. Cross section of heater test apparatus.

The heater cavity and the gap between the cylinder and the cooling jacket are filled with a helium-argon gas mixture, the exact composition of which is adjusted to produce a wide range of power demands for a given cylinder surface temperature. A cross-section of the heater test apparatus is illustrated in Fig. 23. Typical test data relate heater temperature to input power and molybdenum-cylinder surface temperature.

- The first heater-lifetime test stand to perform extended laboratory heater lifetime tests has been built. One unit has been completed and five more stations are being constructed. The heater lifetime test stands are similar in design and operation to the heater test apparatus. The first lifetime test was terminated after 720 ks (200 h) although the heater was still performing satisfactorily. Data from these tests will be used for reliable estimates of prototype heater lifetimes.
- Design concepts have been formulated for high-advance-rate penetrator heaters aimed toward supplying more thermal energy directly to the leading edge of the penetrator.

- The low-temperature resistivity of a supply of pyrolytic graphite was measured so that future heater fabrication can utilize these resistivity differences to meet design needs.
- The use of a TaC-coated receptor to reduce the carburization of the molybdenum penetrator body has been verified in the laboratory. Test operating conditions were: body surface temperature, 1800 K; heater temperature 2450 K; power input, 4.6 kW; and a heater surface heat flux of ~ 1.4 MW/m^2.
- Annular or ring-shaped pyrolytic-graphite heaters have been designed and characterized for use in UEP and ACP designs. Heaters of this design have been operated in laboratory tests of the ACP and performance was essentially as predicted.

3. Alternatives to Direct Resistance Heating

One possible approach to increasing the heat flux at the leading edge of penetrators and also alleviating the need for very high currents in higher-power-demand systems is to employ electron-beam heating of the penetrator body. The energy in the beam can be controlled over a wide range of voltages and currents, and stem design can be focused on insulating for the higher voltages with conductors of relatively small cross sectional area. One design employs a diode gun structure with the cathode in the form of a concentric double tube. Initially, heat is supplied to raise the cathode to its operating temperature of ~ 2500 K by direct resistance-heating. As the penetrator body reaches its operating temperature of ~ 1800 K, only a small amount of power would be required to maintain cathode temperature. Electron emission from the cathode is a strong function of temperature, and the desired voltage-current relationship is therefore maintained by controlling the heating current applied to the cathode.

The second design uses an electron gun with a suitable beam-shaping anode plate. The relatively small cathode area can be heated initially by a lower current than the diode design, and this current would be reduced further as the penetrator body approaches its operating temperature.

In addition, the use of high-temperature liquid-metal heat pipes for enhancing the energy flow to critical penetrator areas is being studied. High thermal heat fluxes, low operating temperature gradients, and the ability to locate the heat source remotely are a few of the potential advantages of heat-pipe systems.

B. Power Source Controls

The design, construction, and calibration of a digital readout system for monitoring penetrator power, voltage, current, and heater resistance for both laboratory and field-test operation has been completed. The design and fabrication of an automatic power-system control unit to be used initially as a part of the lifetime test stands has commenced. This unit will be incorporated into a more sophisticated advance rate-power control system including feedback control loops.

V. FIELD TEST AND DEMONSTRATIONS

A. Field Demonstration Units

1. Introduction

The principal objectives of field-testing complete penetrator systems are the performance evaluation of the system under actual field conditions and the acquisition of realistic data on system reliability and expected service life. Data and experience from field tests form an important input in the penetrator-system design-optimization process. Field tests also demonstrate prototype system performance at a level of development approaching that required for commercial applications.

The field-test program was established with the design, construction, and utilization of the first portable, modularized field-demonstration unit (FDU). This initial FDU provided a self-contained unit for demonstrating small-diameter rock-melting penetration system capabilities at locations away from the immediate Los Alamos area. The unit was designed to produce glass-lined bores in low-density rocks or soils and to achieve the following specific objectives:

- Provide field demonstrations of basic rock-melting principles and capabilities.
- Produce glass-lined drainage holes in archaeological ruins.
- Melt prototype utility holes under roadways.
- Test improved glass-forming designs.
- Provide extended-lifetime test data for the refractory metal penetrators.
- Serve as a prototype and yield data and experience for the design of larger units for future field tests of Subterrene systems.

The FDU is easily transportable and capable of remote, self-contained operation utilizing an air-cooled stem in place of the laboratory water or inert-gas cooling systems. A schematic sketch of the completed FDU is shown in Fig. 24. The various modularized components are designed to be stored and transported in one trailer.

The major components of the FDU and their basic functions are described below:

- Thruster - Two double-acting hydraulic cylinders and a mechanical chuck are used for gripping the stem and thrusting the heated penetrator into the rock formation and also for extracting the penetrator.

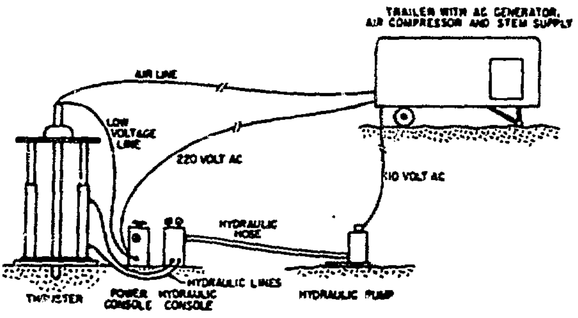


Fig. 24. Schematic of initial field-demonstration unit.

- Hydraulic Power Supply and Control Console - An electric-motor-driven hydraulic pump supplies pressurized oil to the control console for use in operating the thruster. The control console provides control of the thruster (i.e., of its direction and amount of thrust applied) by means of regulating valves. An accumulator in this console provides a reservoir of available hydraulic power for rapid movement of the thruster or for emergency use in retracting the penetrator in the event of an electrical failure.
- Electric Power Supply and Control Console - Electrical power is supplied by a gasoline-engine-driven generator which provides ~ 10 kW of 240-V single-phase 60-Hz power. The control console modulates the power to the penetrator and contains a rectifier to change the 60-Hz to direct current, a step-down transformer to provide lower-voltage/higher-amperage power, a Variac for voltage control, and associated instrumentation.
- Air Compressor - A gasoline-engine-powered air compressor is used to supply cooling air to the penetrator stem and for chilling the rock-glass lining.
- Melting-Consolidating Penetrator - This part is a sealed penetrator unit designed to operate with the air-cooled stem for penetrating porous rocks and soils.
- Stem Sections - Modified sections of standard drill rod commonly used in oil-field drilling are used. They are fitted with an internal

Fig. 25. Consolidating penetrator at exit of ~ 15-m-long horizontal hole in tuff.

copper tube which serves as a conduit for the cooling air and as a conductor for the electrical power to the penetrator heater.

2. Technical Achievements

Significant technical achievements in this area include:

- The design, fabrication, and successful utilization of two field-demonstration units for use with 50-mm-diam air-cooled, sealed, consolidating penetrators.
- The use of a FDU to make a 13-m and a 15-m horizontal penetration into Bandelier tuff. The exiting penetrator is shown in Fig. 25 for the 15-m-long hole, and the field-demonstration unit is shown in place in Fig. 26.
- Two very straight glass-lined holes, one vertical and one horizontal, have been produced in Bandelier tuff with a field-demonstration unit. These holes are each ~ 13 m long and deviate from straightness by less than 10 mm along their entire length.
- Numerous penetrations into various loose and unconsolidated soil samples, including layered samples formed from different loose materials, have been conducted to examine the resulting glass liners. The glass liners have been of good quality and the smooth transition across the layered samples was particularly encouraging.
- Eight water drainage holes were melted with a FDU at the Rainbow House and Tyuonyi archaeological ruins at Bandelier National Monument, NM, in cooperation with the National Park Service. By utilizing a consolidation penetrator, the required glass-lined drainage holes were made without creating debris or endangering the ruins from mechanical vibrations. Fig. 27 shows the rock-melting demonstration unit in place at Rainbow House and Fig. 28 shows the unit at the plaza in the Tyuonyi ruins. Specifically, this operation has shown the following:

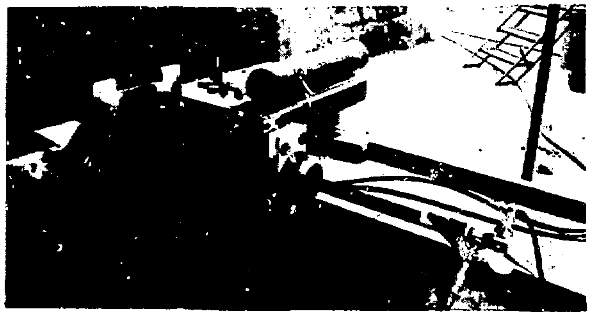


Fig. 26. Field-demonstration unit in position for horizontal penetration.

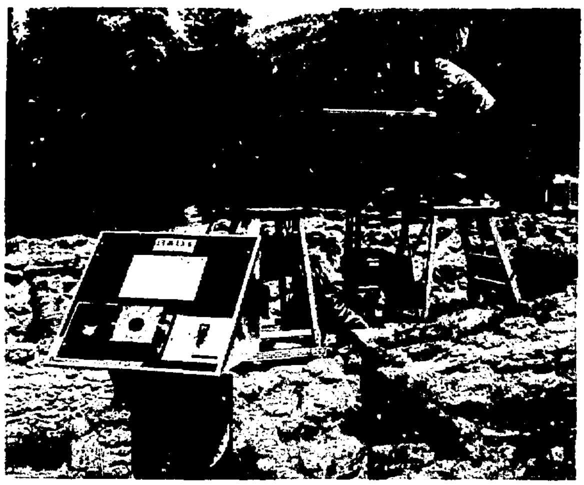


Fig. 27. Rock-melting demonstration unit at Rainbow House ruins.

Fig. 28. Rock-melting demonstration unit at Tyuonyi ruins.

(1) Subterrenes can be operated successfully under field conditions and in areas remote from the laboratory.

(2) The consolidating penetrator can make its way through alluvial formations containing some moderately sized basaltic rocks by thermally cracking the rocks and forcing the melt into the surrounding soil through the cracks.

(3) The Subterrene has demonstrated its first useful and unique application and has been established as more than a laboratory device.

- The Subterrene rock-melting unit was turned over to the National Park Service (NPS) after completion of the first five holes at Bandelier and after suitable training of NPS personnel. The NPS subsequently melted three more holes with minimal LASL supervision.
- A field-demonstration unit which will operate with a 66-mm-diam universal extrusion penetrator for hard-rock penetrations has been designed, fabricated, and successfully tested in basalt.

3. Public Demonstrations

The initial melting of drainage holes in Indian ruins at Bandelier National Monument has been completed. Considerable interest in the Subterrene operation was shown by the tourists and visitors to the Monument. An invitation has been received to conduct a Subterrene demonstration in Washington, DC, in early October. Plans for this event are in progress, a site has been selected, and the penetrator equipment and mobilization trailers are available.

B. Large Diameter, Mobile Test Rig

The design of a mobile test rig has been completed and the unit is being fabricated. This rig will be used with penetrators from 50 to 127 mm in diameter, with initial testing accomplished with the 114-mm-diam alluvium-coring penetrator. The primary components of the rig are:

- Trailer-mounted thruster and stem tower.
- 125-kW electric power supply.
- 125-kW rectifier and power conditioner.
- Control consoles, instrumentation displays, and recording equipment.

The thruster will be able to support pipe stems 300 m long and will produce a downward force of 80,000 kN. Through the use of a double set of gripping mechanisms and dual thruster systems, the unit will provide continuous movement of the stem during field melting operations.

C. Tower Rig

Melting Consolidating Penetrator systems of 50 mm diameter were used to melt several vertical holes in local Bandelier tuff to depths of 16 and 25 m. These experiments were significant because the holes were made continuously under field conditions into undisturbed in situ volcanic rock. However, the electric-power, stem-cooling, and instrumentation systems were derived from laboratory facilities.

The test stand consisted of an 18-m-tall rigging tower which supported (1) the stem-and-penetrator assembly during hole melting; and (2) the pulldown assembly that guided the MCP into the ground. Figure 29 shows the tower rig and Table I lists the operating performance parameters for the 16- and 25-m-deep holes.

Two 8-m-deep holes ~ 300 mm in diameter have been drilled in the tuff formation under this rig and filled with alluvium from the Nevada Test Site so that the 114-mm-diam alluvium coring penetrator can be tested without moving the tower rig from its present location. A modified thruster has been installed and the tower rig is ready for testing the coring penetrator.

TABLE I

TYPICAL OPERATING PERFORMANCE PARAMETERS FOR 16- AND 25-m-DEEP HOLES MADE IN TUFF

Materials	Input	Results
Rock, local volcanic tuff	Voltage, 32 V	Hole diameter, 50 mm
Penetrator body and tip, molybdenum	Current, 110 A	Total penetration, 15.5 and 25.0 m
Heater, pyrolytic graphite	Total electric power, 3.5 kW	Penetration rate, ~ 0.2 mm/s
Stem, steel tubing	Penetrator temperature, ~ 1870 K	
Stem coolant, nitrogen gas	Heater temperature, ~ 2500 K	
	Downward thrust, 4.5 to 13.3 kN	
	Downward stroke increment, 0.9 m	
	Withdrawal force required, 6.7 kN	

D. Penetrator Life Test Facility

A facility is being designed to test the long-term abrasion and corrosion wear rate of melting penetrators. The facility will consist of two units, each of which will control the operation of two penetrators. The penetrators will travel in 5-m-long troughs filled with alluvium or other types of compacted soils or rocks. After each test run the glass linings will be removed and new material will be added to the troughs for the next test. The facility will be housed in a sheltered area to control the moisture content of the materials and to permit extended, uninterrupted operation.

E. Test Site Location and Preparation

A basalt formation in Ancho Canyon near Los Alamos has been selected as the Subterrene Basalt Test Site (designated as LASL Technical Area 56) for field demonstration of extruding penetrators. Overburden has been removed to expose the surface of the basalt layer for convenience in conducting the field tests. Easy access has been provided to this area, and the 66-mm-diam FDU has been assembled and is operating at this location.

Fig. 29. Tower rig for melting holes with preassembled stem length of ~ 15 m. Rigged for melting holes in tuff with a MCP.

A. Large Tunneler Design and System Definition Study

1. Introduction and Conceptual Design

The most challenging and potentially significant application of the rock-melting concept is its adaptation to a large, continuous tunneling machine. The extension of the technology to a large-diameter concept is a natural outgrowth of the program in progress at LASL to develop small prototype penetrators. The list of existing and potential applications for rapidly produced, relatively inexpensive large holes, tunnels, and underground excavations is very long and offers solutions to many of man's most urgent ecological and technological problems. The implementation of these applications while protecting the environment and preserving the natural landscape is the goal of advancements in excavation technology.

In their 1968 publication on the subject of rapid excavation, the Committee on Rapid Excavation of the National Research Council (NRC) defined ten specific individual research projects that should be pursued on the basis of their potential contribution to the field of underground excavation. Of these ten recommended research projects, no less than seven are directly relevant to the research activities on rock-melting technology and its application to the large-tunneler concept and to an automated geological coring device termed Geoprospector.

Unlike the small-diameter applications of the rock-melting concept where a single technique for material removal may be utilized, the volume requirements of a large tunneler system lead quite naturally to a combination of such techniques. Although numerous combinations of penetration-mode techniques appear feasible, two combinations are noteworthy because they attack the two extremes of undesirable ground conditions. A conceptual design of the penetrating face of a tunnel-boring machine for soft or unconsolidated ground utilizing the rock-melting kerfing technique is illustrated in Fig. 30. The tunnel bore is formed by a series of segmented peripheral kerf-melting elements. The unsymmetrical profile of these kerfing elements directs the melted rock radially outward to form a thick molten layer utilizing density consolidation for melt disposal. A glass-forming section, located directly behind the melting elements, conditions the molten rock into a smooth, continuous, glass tunnel lining. The individual segments forming the peripheral kerf melter could be serviced or replaced as separate units. An array of conventional soft-ground mechanical cutters is located on a rotating face contained within the peripheral kerf melter. Gage cutters are not required as a result of the melted and glass-lined tunnel bore and a continuous conveyor or hydraulic slurry pipeline could be used for conventional muck removal.

A conceptual design of the penetrating face of a tunnel-boring machine for hard, dense, and abrasive rock incorporating the rock-melting kerfing technique and thermal-stress fracturing is illustrated in Fig. 31. The tunnel bore is again formed by a series of segmented peripheral kerf-melting elements. These elements employ the universal melt-extruding concept and direct the melted debris to a continuous removal system leaving only a thin molten layer along the tunnel bore. A glass-forming section conditions this molten rock into a smooth, continuous glass lining. An array of small-diameter universal melt-extruding penetrators is located on the machine face contained within the peripheral kerf melter. These penetrators advance behind the melting kerf in a pattern sufficiently dense to cause thermal-stress fracturing of the heat-affected rock. The melted debris from these small-diameter penetrators is directed to the continuous melt-removal system. The concept envisions the use of many closely spaced small-diameter penetrators to keep the total melted volume low while still initiating high thermal stresses in the rock regions between adjacent penetrators. The muck resulting from thermal-stress fracturing could be either removed by a separate conventional system or mixed with the melt debris and introduced into a fluidized pipeline transport system.

2. Nuclear Subterrene Tunneling Machine (NSTM)

Based on preliminary calculations, a power-source requirement of ~ 15 MW (thermal) would be required for a kerf-melting tunneler for desirable penetration rates in the 6-m-diam range. Although electric heaters will be studied for a variety of geometries and power levels, it is anticipated that

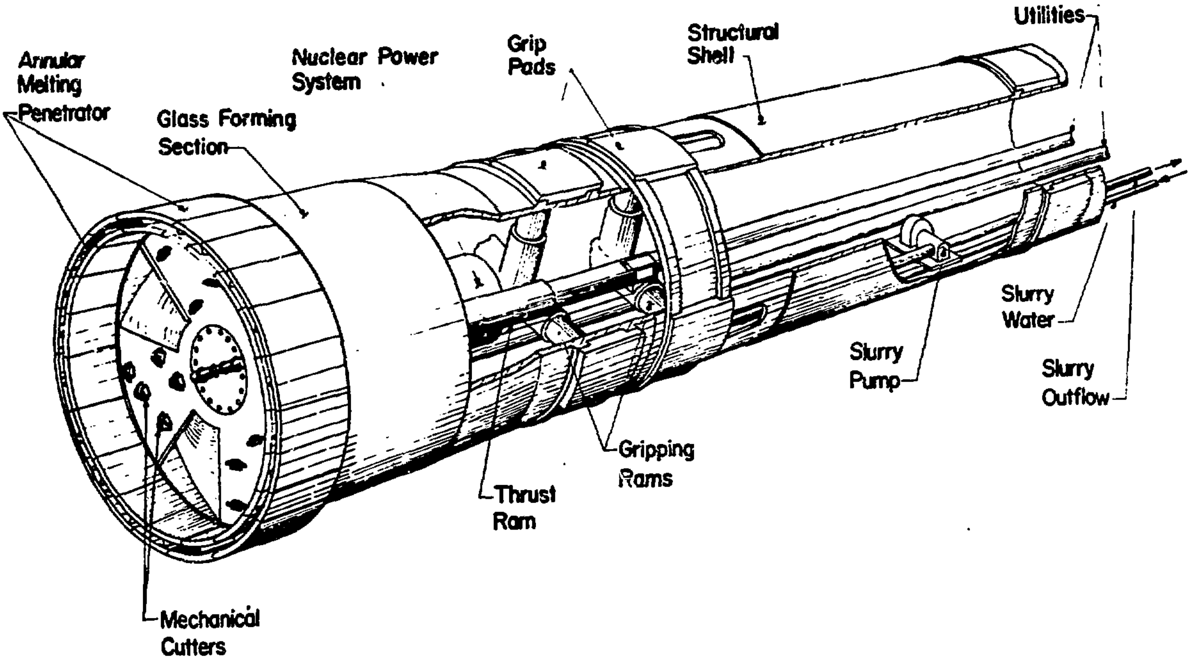


Fig. 30. Design concept of the penetrating face of a soft-ground rock-melting tunneler utilizing the kerfing technique.

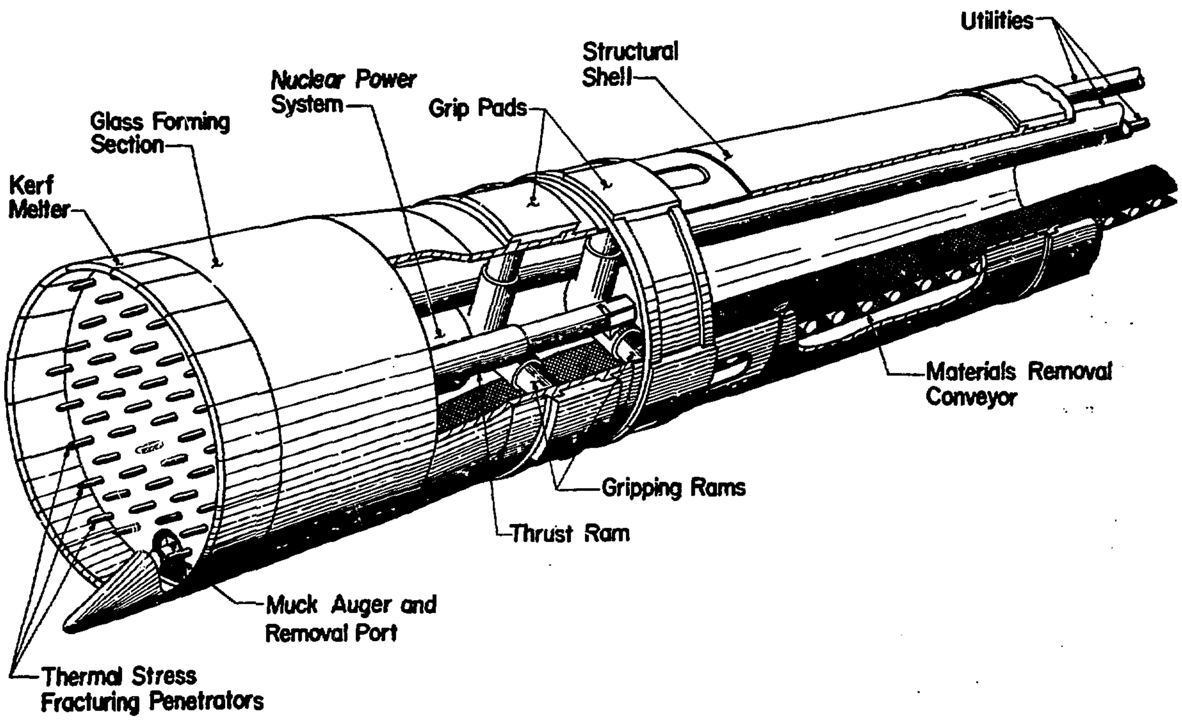


Fig. 31. Design concept of the penetrating face of a hard-rock melting tunneler utilizing the kerfing technique and thermal stress fracturing.

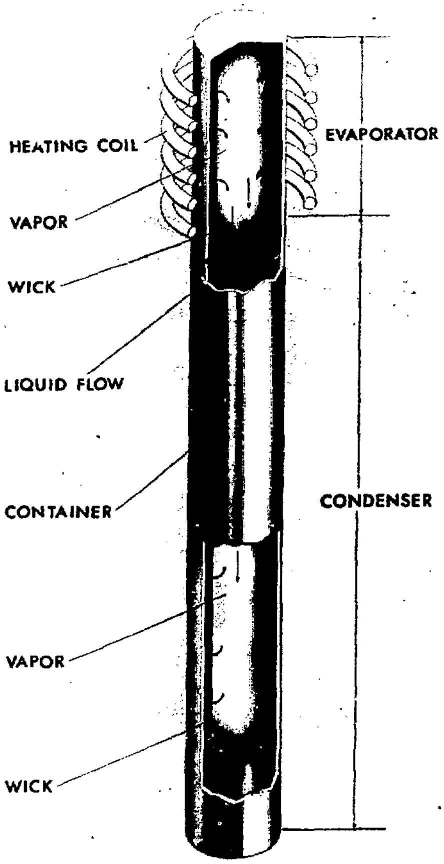


Fig. 32. Basic components of a liquid-metal heat pipe.

economic and technological tradeoffs will favor a compact nuclear power source at a total power requirement less than 10 MW. A compact nuclear reactor could supply the energy for even a very large penetrator advancing at a high rate and would permit the conceptual design of a self-contained unit controlled by telemetry from the surface. The size of such a source, even including elaborate shielding, would allow its use in diameters appreciably smaller than the 6-m size used as an example.

Development work on systems that would optimize the energy transfer from the power source to an array of melting penetrators has led to the utilization of the LASL-developed heat-pipe technique for both nuclear and larger electrical sources. For Subterrene applications, the evaporator end of the heat pipe is embedded within the electrical or nuclear heat source, and the condenser section would be adjacent to the rock-melting surface. The basic components of a liquid-metal heat pipe are illustrated in Fig. 32.

The general field of heat-pipe-cooled nuclear reactors has been investigated at LASL, and experimental work has been performed to establish the feasibility of such designs. The use of heat pipes for cooling and transferring energy from a reactor is attractive because it permits the design of highly redundant systems. The conceptual design of a compact nuclear reactor which could be adapted for Subterrene application is shown in Fig. 33. Numerous heat pipes transport the reactor energy to the melting face of the penetrator. Two-dimensional heat-transfer calculations have indicated that a sufficient number of heat pipes of overdesigned capacity can be included in such a design to permit sustained operation of the reactor with allowable fuel-element temperatures in the event of isolated heat-pipe failures. Reactor power is controlled through the use of multiple control rods which are withdrawn through the aft radiation shield.

3. Potential Sources of Economic and Technological Gains

Stressing the total system concept, the objective is to provide a well-matched tunneling concept that attacks the three major aspects of tunneling: excavation, materials handling, and supports and linings. Although novel rock-disintegration techniques have been categorically criticized on the basis of their higher specific-energy consumption, the fact that power costs represent a very small percentage of the tunnel cost has been documented. The following potential advantages of NSTMs are noted:

- The elimination of temporary tunnel supports by substituting a formed-in-place glass lining, especially in weak and broken rock.
- The elimination of permanent tunnel linings in those applications for which the formed glass lining is independently adequate.
- Cost reductions resulting from the use of completely prefabricated permanent tunnel linings made possible by the dimensionally stable and precise geometry of the glass linings.
- Penetration-rate advances in hard rock by the use of a continuous process as opposed to the intermittent drill-and-blast technique.

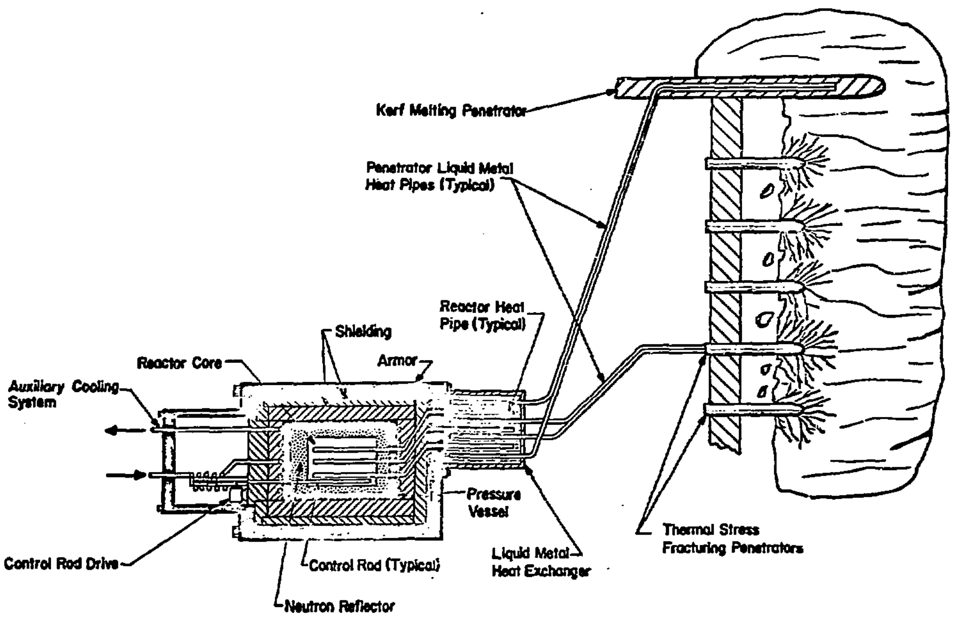


Fig. 33. Schematic of a shielded, heat-pipe-cooled nuclear reactor for Subterrene applications.

- Penetration-rate advances in loose or unconsolidated ground through the elimination of the serious risk of roof failure.
- Additional tunnel stability through the use of a hard-rock disintegration technique that preserves rather than reduces the inherent strength of the unexcavated rock mass.
- Reductions in tunneling-machine downtime through the elimination of gage cutters and reductions in the number of mechanically wearing components.
- Reductions in excavation cost resulting from the ability to produce bores of any desired cross-sectional shape.
- Improved environmental control through the elimination of hazards resulting from excessive dust, noise, ground shock, fumes, and ground collapse.

B. Theoretical Analysis

1. Introduction

Theoretical analysis research has progressed in both the analytical formulation and the numerical analysis directions. Efforts have been directed toward the development of new analytical and numerical techniques for analyzing the combined fluid dynamic and heat-transfer (lithothermodynamic) performance of melting penetrators and the application of these techniques to specific penetrator designs and concepts. Numerous thermal analyses involving two-dimensional heat-conduction solutions have been performed in support of the prototype design and development effort to predict temperature profiles in critical regions of penetrator systems.

2. Computer Code Development

The analytical problem of a heated penetrator advancing into solid rock requires a study of the nonlinear fluid dynamics of creeping viscous flow with high thermal flux-energy interactions. Although some aspects of the analysis are similar to classical areas of investigation in slow viscous flow theory, the complete problem formulation respresents a discipline of its own. Solutions will be characterized by the following features:

- The characteristic fluid velocities involved are very low even for the most optimistic penetration rates. As a consequence, the fluid dynamics problem is inherently incompressible and the very low Reynold's numbers allow the inertia terms to be neglected in the Navier Stokes equations.
- The viscosity of the melted rock materials is very high and strongly temperature-dependent.

- Initially, only steady-state axisymmetric solutions need be considered.
- In addition to the sensible-heat transfer, an effective latent heat of melting must be included in the thermal energy balance.
- The energy contribution from viscous heating is negligible and hence the dissipation function can be neglected in the energy equation.

The motion of a heated penetrator through a melting medium can be formulated in terms of the partial differential equations governing the physics of the process. In axisymmetric cylindrical coordinates (r, z) with radial velocity v_r and axial velocity v_z, these equations are:

$$\frac{1}{r}\frac{\partial}{\partial r}(r\, v_r) + \frac{\partial v_z}{\partial z} = 0,$$ the continuity equation;

$$\frac{\partial P}{\partial r} = \frac{2}{r}\frac{\partial}{\partial r}\left(\mu r \frac{\partial v_r}{\partial r}\right) - \frac{2\mu v_r}{r^2} + \frac{\partial}{\partial z}\left[\mu\left(\frac{\partial v_z}{\partial r} + \frac{\partial v_r}{\partial z}\right)\right],$$

the r-direction Navier Stokes equation;

$$\frac{\partial P}{\partial z} = \frac{1}{r}\frac{\partial}{\partial r}\left[\mu r\left(\frac{\partial v_z}{\partial r} + \frac{\partial v_r}{\partial z}\right)\right] + 2\frac{\partial}{\partial z}\left(\mu \frac{\partial v_z}{\partial z}\right),$$

the z-direction Navier Stokes equation; and

$$\rho c\left(v_r \frac{\partial T}{\partial r} + v_z \frac{\partial T}{\partial z}\right) = \frac{1}{r}\frac{\partial}{\partial r}\left(r\lambda \frac{\partial T}{\partial r}\right) + \frac{\partial}{\partial z}\left(\lambda \frac{\partial T}{\partial z}\right)$$

the energy equation;

where P is the pressure and μ, ρ, c, λ, and T are the rock-melt dynamic viscosity, density, specific heat, thermal conductivity, and temperature, respectively.

In consideration of the typical penetrator geometries, it is convenient to cast these equations in a general curvilinear orthogonal coordinate system that corresponds to the melting penetrator shape. This generalized coordinate system is illustrated in Fig. 34 where the new transverse coordinate is η, the meridional or streamwise coordinate is S, ℓ is the local melt-layer thickness, and β_o is the angle between the penetrator surface and the axis of revolution.

Rewriting the basic equations in the new coordinate system and neglecting lower-order terms, the simplified equations are:

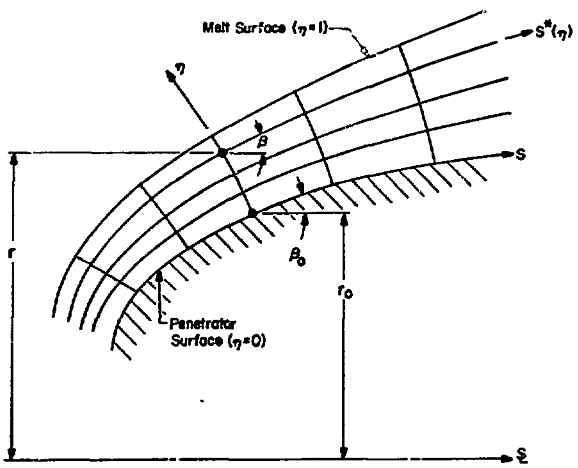


Fig. 34. General curvilinear orthogonal coordinate system.

$$\frac{\partial}{\partial \eta}(\sigma r v) + \frac{\partial}{\partial S}(\ell r u) = 0,$$ the continuity equation;

$$\frac{\partial}{\partial \eta}\left[\sigma^3 r \mu \frac{\partial}{\partial \eta}\left(\frac{u}{\sigma}\right)\right] = \sigma\, \ell^2 r \frac{dP}{dS},$$

the S-direction Navier Stokes equation; and

$$\frac{\partial}{\partial \eta}\left(\sigma\, r\, \lambda \frac{\partial T}{\partial \eta}\right) = \sigma\, \ell\, r\, \rho\, c\, v \frac{\partial T}{\partial \eta} + \ell^2 r\, \rho\, c\, u \frac{\partial T}{\partial S},$$

the energy equation;

where v is the transverse velocity component, u is the meridional velocity component, and $\sigma = (dS^*/dS)_\eta$ where S^* is the meridional distance along any constant η line. As in typical boundary layer theory, the η direction Navier Stokes equation contains only lower-order terms and is replaced in this case with an integral form of the continuity equation.

These equations, together with appropriate boundary conditions, have been solved numerically by using a finite-difference technique. The results have been incorporated into a computer program for performing detailed lithothermodynamic analyses of melting penetrators.

For future stress-analysis calculations on penetrator bodies, extraction, and stem components, a new computer program named PLACID has been developed. PLACID is a finite-element stress-analysis program capable of generating plane stress, plane strain, and axisymmetric solutions. A unique feature of this code is that all input is programmed by the

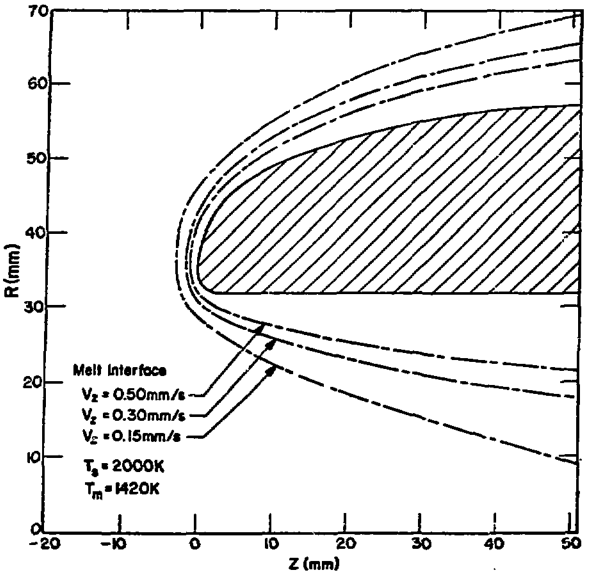


Fig. 35. Melt interface location as a function of penetration rate for an alluvium-coring penetrator.

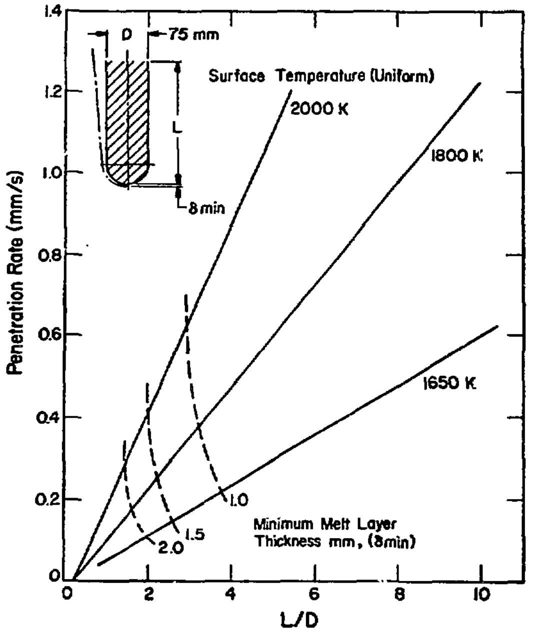


Fig. 36. Calculated lithothermodynamic performance of a hemisphere-cylinder consolidating penetrator in tuff.

user via subroutines. As a result, material properties can be nonlinear, time- and/or temperature-dependent, and can also possess three-dimensional anisotropy.

3. Significant Analytical Results

Noteworthy technical achievements in this area include:

- Utilizing the newly developed lithothermodynamic computer program, calculations have been performed for the 114-mm-diam alluvium-coring penetrator. These calculations indicate that the penetration rate will be ~ 0.2 mm/s for a uniform surface temperature of 2000 K and typical conductivities of solid and melted rock. For a uniform penetrator surface temperature of 1800 K, the penetration rate decreases approximately linearly with the decreasing temperature difference available for melting. Calculated results for the melt-to-solid interface location for various penetration rates in tuff are shown in Fig. 35.
- Calculations were performed to predict the significant lithothermodynamic characteristics of the high-advance-rate 82-mm-diam UEP. The predicted performance map for this penetrator design melting in basalt was presented in Section II-B of this report.
- Parametric lithothermodynamic analyses have been conducted on consolidating penetrators with different geometrical shapes. Calculational results for a hemisphere-cylinder geometry based on typical local tuff properties are shown in Fig. 36. The theoretical penetration rate in the consolidation mode is shown to be proportional to the heated length of the penetrator as represented by the length-to-diameter ratio for a 75-mm-diam penetrator. As indicated by the cross-plot lines of constant melt-layer thickness at the penetrator tip, the maximum penetration rate could be limited by unmelted hard particles such as quartz crystals. Note that the calculational results presented in Fig. 36 do not satisfy the consolidation relation locally, but only require that the melt layer at the end of the heated penetrator afterbody be sufficiently thick for complete density consolidation of the melt. Penetrators exhibiting this type of melt-layer control will be referred to as Melt Transfer Consolidation (MTC) penetrators

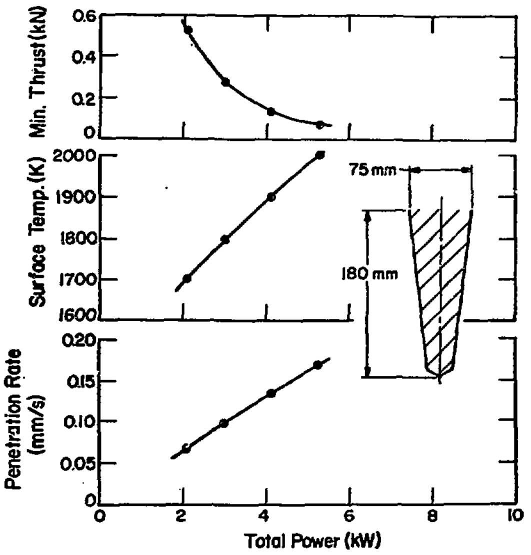


Fig. 37. Calculated lithothermodynamic performance of a double-cone consolidating penetrator in tuff.

to denote the fact that molten rock is transferred according to a calculated axial velocity profile from the leading-edge surfaces of the penetrator to its afterbody where the final density consolidation melt-layer thickness relation is satisfied.

- The calculated penetration rate, surface temperature, and minimum thrust requirement as a function of heating power (not including stem-conduction losses) for the 75-mm-diam consolidating penetrator are shown in Fig. 37. These calculations show that the theoretical penetration rate of this double-cone shape is considerably lower than that of the hemisphere-cylinder geometry shown in Fig. 36 for the same surface temperature and the same length-to-diameter (L/D) ratio. This conclusion was also verified for a parabolic penetrator, indicating the importance of penetrator geometry on advance rate. The rapidly decreasing minimum thrust depicted in Fig. 37 is a result of the strongly decreasing viscosity associated with the higher penetrator surface temperatures.

- A theoretical investigation on the effectiveness of extended melting surfaces was performed. For UEPs, extended melting surfaces can be used advantageously particularly when combined with multiple melt-removal ports which direct the external melt to the interior of the penetrator. By preserving a thin external melt layer, the effectiveness of the extended surfaces is greatly enhanced. In the consolidation mode, however, the melt layer can only be kept thin over the leading edge of the penetrator and the potential advantages of extended melting surfaces rapidly diminish along the remainder of the penetrator body.

C. Systems Integration and Model Studies

The first major systems integration and model study, incorporating both technical and economic model developments, has been performed for the large tunneler concept. Three specific objectives were established for this study: First, to develop technically sound conceptual designs of nuclear Subterrene tunneling machines (NSTMs). Second, to make a cost comparison between the conceptual NSTMs and tunneling with Tunnel Boring Machines (TBMs) or conventional excavation methods. And third, to determine the benefit-to-cost ratio for a projected major Subterrene development program costing $\sim$ \$100 x 10^6 over an eight-year period. The basic characteristics and assumptions involved in the systems model development are outlined below:

- Two conceptual designs for NSTMs, similar to those described in Section VI-A, were utilized in the model study.
- Tunnel sizes studied ranged from 4 to 12 m finished diameter and the average operational sustained advance rate was 1.5 m/h.
- Thermal energy for rock-melting was obtained from a compact nuclear reactor with liquid-metal heat pipes being used to distribute the energy to the rock-melting face.
- The NSTM-generated glass tunnel liners eliminated any other form of temporary support. The glass liner thicknesses assumed for costing purposes were 4% of the finished tunnel diameter for unfavorable conditions and 2% of the finished tunnel diameter for sound, hard rock.

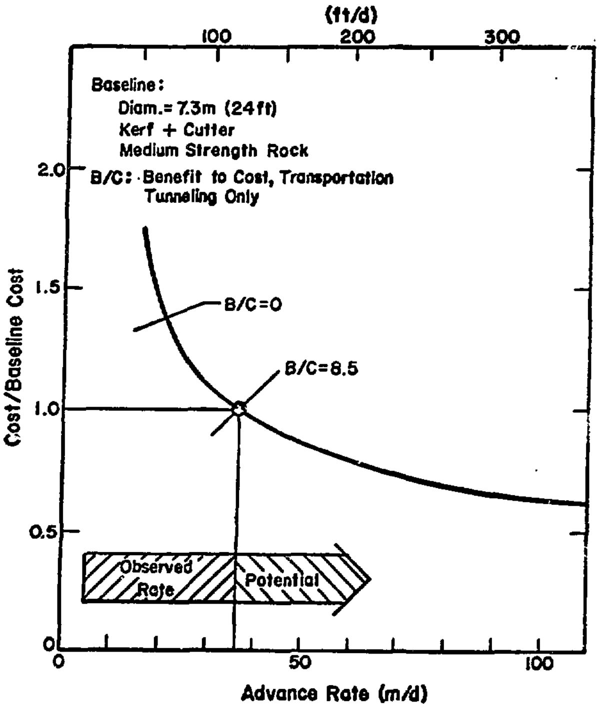


Fig. 38. Effect of advance rate on baseline tunnel cost.

- The permanent tunnel liners consisted of the rock glass plus a conventional concrete liner, with overall liner thickness equaling 8% of the tunnel diameter.
- The excavation face was sealed by the NSTM; muck removal was by the hydraulic-slurry method; and the glass liner, reactor components, and tunnel air were water-cooled.

The study results indicated that for very hard rock or unfavorable soft ground (e.g., wet, running, bouldery), average cost savings of NSTMs over TBMs or conventional methods were estimated to be of the order of 30 and 50%, respectively. Excellent cost benefits for the development of NSTM systems were indicated, considering only U.S. transportation demands up to CY 1990. The predicted effect of advance rate on tunnel cost for a baseline case is shown in Fig. 38. Many other potential benefits in addition to transportation applications also exist. The nuclear thermal-power requirements were calculated to be 7 and 63 MW for 4- and 12-m-diam tunnels, respectively, as illustrated in Fig. 39. The

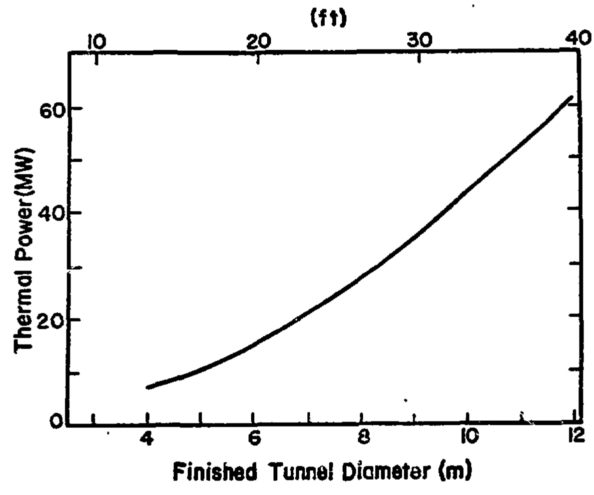


Fig. 39. Reactor thermal power vs finished tunnel diameter.

cost of the thermal power required to melt the rock was ~ 4 to 7% of the total excavation project cost.

D. Applications and Technology Utilization

The number of novel and conventional applications of Subterrene technology that have been investigated continue to increase and range from deep hot-rock penetrations for geothermal-energy exploration to emplacements in arctic permafrost.

Particular interest in small-diameter, horizontal, glass-lined holes motivated a separate study, which has been completed. These small horizontal borings can be used as underground utility conduits for the installation of telephone, gas, water, and television lines; as glass-lined holes for high-explosive shot emplacement; and as drainage holes to stabilize roadcuts and embankments. The study indicates that hole straightness requirements can be met by adding deviation sensors and alignment-control units to the hole-forming assembly.

The technical reports on all phases of Subterrene activities continue to be in demand and are forwarded to all interested parties. Lists of completed and in-progress Subterrene technical reports, including those intended for publication in scientific journals, appear in Section VII. The Subterrene was featured on the front covers of the June 1973 issue of "Mining Engineering" and the July 1973 issue of "Water Well Journal." Both issues contained accompanying articles. An article entitled

"Subterrene Rock Melting Devices-Showing the Way to New Tunneling Techniques" has been prepared at the request of the editor of "Tunnels and Tunnelling" magazine. This publication is the news outlet for the British Tunnelling Society. In conjunction with the large-tunneler study, all major U.S. tunnel-boring machine manufacturers were visited and briefed on the Subterrene concept. Technical comments and suggestions from their engineering staffs were utilized as guidelines in the conceptual NSTM study.

Technical briefings presented to interested individuals and groups by the Subterrene staff continue at the rate of about ten per month. Interested individuals and groups include United States Senators, representatives of major industrial concerns, representatives of the armed forces, utility and power distribution specialists, drilling and oil-field specialists, University professors, technically oriented professional engineers, and college students.

As a result of discussions with Westinghouse Corp., an Industrial Staff Member has been assigned to the LASL Subterrene project and is currently working in the area of penetrator thermal analysis.

A contact was made with Mr. Walter W. Long of the University of New Mexico, NASA Technology Applications Center (TAC). Discussions of the possible interest by TAC in doing a real-time study of the Subterrene technology transfer efforts, methodology, and successes indicated that the TAC would be interested in such a collaborative effort.

The structure of the proposed Subterrene Technology Advisory Panel has been established with the following initial membership:

- Chairman - A person with broad engineering experience.
- One member from a Federal Agency with interest and responsibilities in tunneling and excavation.
- A University professor from a civil, mining, or geological engineering department with well-recognized expertise in excavation technology.
- An economist with expertise in excavation technology (desirable).
- Three representatives from related industries.

Initial impact in the area of public demonstrations has been achieved through the use of a mobile Subterrene field-demonstration unit in Bandelier National Monument, NM. In addition, a short documentary color film on the Subterrene concept has been produced, and narration via a cassette tape will be available shortly.

VII. TECHNICAL REPORTS

Copies of the reports listed below can be obtained from:

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151;

the completed reports are identified by their LA-MS numbers by NTIS.

Discussions of the technical reports can be directed to individual authors at:

University of California
Los Alamos Scientific Laboratory
P.O. Box 1663
Group Q-23
Los Alamos, New Mexico 87544
Telephone: (505) 667-6677

A. COMPLETED TECHNICAL REPORTS

LASL Report No.	Title	Author(s)
LA-4959-MS	Thermodynamic Stability Considerations in the Mo-BN-C System. Application to Prototype Subterrene Penetrators.	M. C. Krupka
LA-5094-MS	Internal Reaction Phenomena in Prototype Subterrene Radiant Heater Penetrators.	M. C. Krupka
LA-5135-MS	Internal Temperature Distribution of a Subterrene Rock-Melting Penetrator.	R. G. Gido
LA-5204-MS	Subterrene Penetration Rate-Melting Power Relationship.	R. G. Gido
LA-5205-MS	Design and Development of Prototype Universal-Extruding Subterrene Penetrators.	J. W. Neudecker A. J. Giger P. E. Armstrong
LA-5206-MS	Identification of Potential Applications for Rock Melting Subterrenes.	D. L. Sims
LA-5207-MS	Heat Loss Calculations for Small Diameter Subterrene Penetrators.	D. J. Murphy R. G. Gido
LA-5208-MS	Phenomena Associated with the Process of Rock-Melting. Application to the Subterrene System.	M. C. Krupka
LA-5209-MS	Development and Construction of a Modularized Mobile Rock-Melting Subterrene Demonstration Unit.	R. E. Williams
LA-5210-MS	Large Subterrene Rock-Melting Tunnel-Excavation Systems. A Preliminary Study.	R. J. Hanold
LA-5212-MS	Design Description of Melting-Consolidating Prototype Subterrene Penetrators.	J. W. Neudecker
LA-5213-MS	Description of Field Tests for Rock Melting Penetration.	R. G. Gido
LA-5354-MS	Systems and Cost Analysis for a Nuclear Subterrene Tunneling Machine - A Preliminary Study.	J. H. Altseimer
LA-5370-MS	Use of the Rock-Melting Subterrene for Formation of Drainage Holes in Archaeological Sites.	R. E. Williams J. E. Griggs

B. TECHNICAL REPORTS IN PROGRESS

Title	Author(s)
Rock Heat-Loss Shape Factors for Subterrene Penetrators.	G. E. Cort
Thermal Design Analysis of a Subterrene Universal Extruding Penetrator.	R. G. Gido G. E. Cort
Description of the AYER Heat Conduction Computer Program.	R. G. Lawton
A Versatile Rock-Melting System for the Formation of Small Diameter Horizontal Glass Lined Holes.	D. L. Sims
Conceptual Design of a Coring Subterrene Geoprospector.	J. W. Neudecker
Numerical Solution of Melt Flow and Thermal Energy Transfer for a Rock-Melting Penetrator - Lithothermodynamics.	R. D. McFarland
PLACID - A General Finite Element Computer Program for Stress Analysis of Plane and Axisymmetric Solids.	R. G. Lawton
Field and Laboratory Results for Consolidating Penetrators from 25 to 75 mm in Diameter.	C. A. Bankston
Unique Refractory Fabrication Techniques for Subterrene Penetrators.	W. C. Turner
Selected Physico-Chemical Properties of Basalt Rock, Liquids, and Glasses.	M. C. Krupka
Carbon Receptor Reaction in Subterrene Penetrators.	W. A. Stark M. C. Krupka
Design, Analysis, and Tests of a Consolidating, Coring Penetrator.	H. D. Murphy, et al

C. PRESENTATIONS AND JOURNAL ARTICLES

University of California Regents (Invited Lecture)

J. C. Rowley	LASL Subterrene Program	Los Alamos, NM April 12-13, 1973.

Committee on Advanced Developments (Invited Presentation)

J. C. Rowley	Subterrene Concepts for Mini-Tunneler for Undergrounding of Power Transmission Lines.	Edison Electric Institute, Los Alamos, NM, May 1, 1973.

Rocky Mountain Science Council (Invited Presentation)

J. C. Rowley	Rock-Melting Excavation and Tunneling.	Los Alamos, NM, May 11-12, 1973.

Aerospace Instrumentation Symposium

J. W. Neudecker	Subterrene Instrumentation Requirements; Instrumentation in the Aerospace Industry, Vol. 19, W. Washburn Ed., pp. 7-10, 1973.	Instrument Society of America, Las Vegas, NV, May 21-23, 1973.

Technical Seminar on Rapid Tunneling & Excavation Technology (Invited Presentation)

J. C. Rowley R. J. Hanold D. L. Sims	The Subterrene Rock-Melting Concept In Future Excavation Technology.	U.S. Air Force, Weapons Laboratory Civil Engr. Res. Div. Albuquerque, NM, May 31, 1973.

	Arkansas River Basin Group (Invited Lecture)	
J. C. Rowley	The LASL Subterrene Program.	Los Alamos, NM, July 17, 1973.
	21st Meeting of National Refractory Composites Working Group (Invited Presentation)	
P. E. Armstrong	Subterrene Penetration Materials.	Los Alamos, NM, July 18-19, 1973.
	Engineering & Planning Committee Meeting (Invited Talk)	
R. J. Hanold J. W. Neudecker	The LASL Subterrene Program.	WEST Associates, Los Alamos, NM, August 13-14, 1973.
	Tunnels & Tunneling (Invited Article)	
J. H. Altseimer	Subterrene Rock Melting Devices -- Showing the Way to New Tunneling Techniques.	British Tunneling Society, September 7, 1973 (Intended for next issue.)
	15th Symposium on Rock Mechanics (Presentation)	
R. J. Hanold	The Subterrene Concept and Its Role in Future Excavation Technology.	U.S. National Comm. on Rock Mechanics & Dept. of Mining Engr., Sept. 17-19, 1973.
	26th Regional Meeting (Presentation, Abstract Accepted)	
M. C. Krupka W. J. Stark	Refractory Material and Glass Technology Problems Associated with the Development of the Subterrene -- A Rock Melting Drill.	American Ceramic Society, Oct. 31-Nov. 2, 1973.
	1974 Offshore Technology Conference (Paper Abstract)	
D. L. Sims	Melting Glass Lined Holes in Rock and Soil with the Los Alamos Scientific Laboratory Subterrene.	SPE of AIME Dallas, TX, May 5-8, 1974.
	24th Heat Transfer & Fluid Mechanics Institute (Abstract)	
R. D. McFarland R. J. Hanold	Viscous Melt Flow and Thermal Energy Transfer for a Rock-Melting Penetrator -- Lithothermodynamics.	Oregon State Univ. Mech. Engr. Dept. Corvallis, OR, June 12-14, 1974.
	3rd International Congress (Abstract Submitted)	
J. C. Rowley	Rock Melting Applied to Excavation & Tunneling.	International Society for Rock Mechanics Denver, CO, September 2-7, 1974.

ALT:511(315)

RC

LA-5354-MS

INFORMAL REPORT

c. 3

Systems and Cost Analysis for a Nuclear Subterrene Tunneling Machine

A Preliminary Study

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

In the interest of prompt distribution, this LAMS report was not edited by the Technical Information staff.

Printed in the United States of America. Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $4.00; Microfiche $0.95

LA-5354-MS
Informal Report
UC-38
ISSUED: September 1973

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

Systems and Cost Analysis for a Nuclear Subterrene Tunneling Machine

A Preliminary Study

by

J. H. Altseimer

Work supported in part by a grant from the National Science Foundation, Research Applied to National Needs (RANN).

SYSTEMS & COST ANALYSIS FOR A NUCLEAR SUBTERRENE TUNNELING MACHINE

- A PRELIMINARY STUDY -

by

J. H. Altseimer

ABSTRACT

The basic system components of large rock-melting Nuclear Subterrene Tunneling Machines (NSTMs) have been conceptualized and defined for a preliminary tunneling cost estimate and comparison with costs using tunnel-boring machines (TBMs) and other conventional tunneling techniques. Two initial types of NSTMs are considered: Type I, peripheral kerf-melting penetrators plus centrally located rotary cutters for soft ground and rock; and Type II, kerf-melting penetrators plus multiple, hot rock-fracturing penetrators for very hard rock. Tunneling costs for NSTMs are very close to those for TBMs, if operating conditions for TBMs are favorable. However, for variable formations and unfavorable conditions such as soft, wet, bouldery ground or very hard rock, the NSTMs are far more effective. Estimates of cost and percentage use of NSTMs to satisfy U.S. transportation tunnel demands indicate a potential cost savings of 850 million dollars (1969 dollars) through 1990. An estimated NSTM prototype demonstration program cost of $100 million over an eight-year period results in a favorable benefit-to-cost ratio of 8.5. The NSTM systems are characterized by large capital costs compared to conventional TBMs. However, many higher-cost items and components are expected to have long service lives and will be used for more than one tunnel project instead of writing off the tunneler after each project as in current TBM practice. The cost of thermal energy for rock melting is not a large percentage of the total project cost.

I. INTRODUCTION

A. Study Objectives

The general study objective, considering the present early stage of Subterrene concept development, was to establish a clear indication of the cost effectiveness of Nuclear Subterrene Tunneling Machines (NSTMs) as applied to national demands for large tunnels. To achieve the above, three specific objectives were established: first, to develop technically sound conceptual designs; second, to make a cost comparison with the conceptual NSTMs on the one hand and tunneling with Tunnel Boring Machines (TBMs) and conventional excavation methods, on the other; and third, to determine the benefit-to-cost ratio for a projected major Subterrene development program costing $\sim \$100 \times 10^6$ over an eight-year period.

B. Subterrene Program Background

The need for innovative approaches to the solution of major problems in excavation and tunneling technology has been summarized in recent publications by the Underground Construction Research Council and the National Academy of Sciences.[1,2] A research and development program in excavation technology, based on rock-melting, is being conducted at the Los Alamos Scientific Laboratory (LASL).[3,4] In addition to identifying many potential applications, this program has indicated that the Subterrene concept can offer, through an integrated tunneling system, solutions to the multiple problems in the three important areas of conventional tunneling technology:

- Forming the hole.

- Maintaining wall integrity and forming a primary support.
- Removing the debris.

The program has also indicated that the rate of penetration in varying geological formations can be predicted and is relatively insensitive to the material being melted.[5] In addition, the input power requirements for small-diameter, electrically heated Subterrene devices are easily handled with conventional equipment, as has been substantiated by LASL laboratory and field tests.[6] A recent study of current tunneling systems and economics indicated the areas in which a Subterrene system could significantly contribute to advancing the tunneling and excavation technology.[7] The study also contains an extensive and selected bibliography and should be considered as complementing this report.

While electric heating appears to be quite practical for small Subterrene devices, a nuclear-powered subsystem was assumed to be most feasible for the sizes considered in this report. A detailed technical and cost-tradeoff study to establish crossover points between electric and nuclear systems has yet to be conducted, but indications are that a demand of ~ 10 MW (electric) may be the level above which practical considerations of power supply and distribution become unattractive for an electrically heated system. This demand is in the approximate power-level range needed for the smallest tunnel considered in this report. A cost advantage of the nuclear subsystem is offered by the fact that thermal energy is applied directly to the rock and that the circuitous procedure of an electric system can be avoided in which thermal energy is generated, converted to electricity (at an efficiency of ≈ 30%), and then converted back to thermal energy at the rock-melting penetrator bits. Another advantage is that the nuclear subsystem can make the tunneling system almost completely self-sufficient, minimizing external expenses such as large specially installed power lines to the tunnel portal. Other characteristics that make a nuclear subsystem feasible are: (1) compactness, i.e., reactor diameters of 1 to 2 m, thus fitting into even a small 4-m tunneling machine; (2) lack of rotating or moving components except control rods or drums; (3) low containment pressures due to the use of heat pipes to transfer heat out of the reactor core; and, (4) sufficiently long component operational lifetimes to be useful for this application.

The chemical generation of heat has been considered in a report by Hanold.[7] It was found to be unattractive for various operational and environmental reasons and therefore was not considered for this study.

C. General System Assumptions

A circular tunnel cross section was assumed for convenience in calculating power requirements and to facilitate the comparison with TBMs which are, of necessity, circular. No economic advantage was taken from the fact that NSTMs can form noncircular cross sections, which could minimize the excavation volume and automatically incorporate features such as utility line gangways or partially finished roadway surfaces.

The finished tunnel diameters* studied ranged from 4.0 m (~ 13 ft) upward. The minimum diameter of 4.0 m was chosen because the required melting power (≈ 7 MW) appears high enough for economical use of nuclear devices and because the envelope is clearly large enough for their accommodation at this stage of development. No maximum-diameter limitations for NSTMs have yet been established. Any such limitations would probably result from practical considerations external to the NSTM equipment. Such a constraint might result from excessive tunnel support requirements due to large structural span dimensions.

Two basic NSTM design concepts were considered in this preliminary study. Both were chosen because they appear to be logical progressions from existing technology incorporating the new nuclear Subterrene designs, and both require only partial melting of the working face. (Applications in which the excavation face is almost or completely melted will be examined at a later date as well as many other conceivable design variations.) The two concepts considered are illustrated in Figs. 1 and 2. The conceptual designs are:

- Type I--uses a peripheral kerf penetrator to form the tunnel wall, whereas the main excavation face is removed by mechanical rotary cutters. This device is intended for use in softer formations.

*Throughout this report the finished tunnel diameter refers to the inner diameter of the completed tunnel, including final support lining.

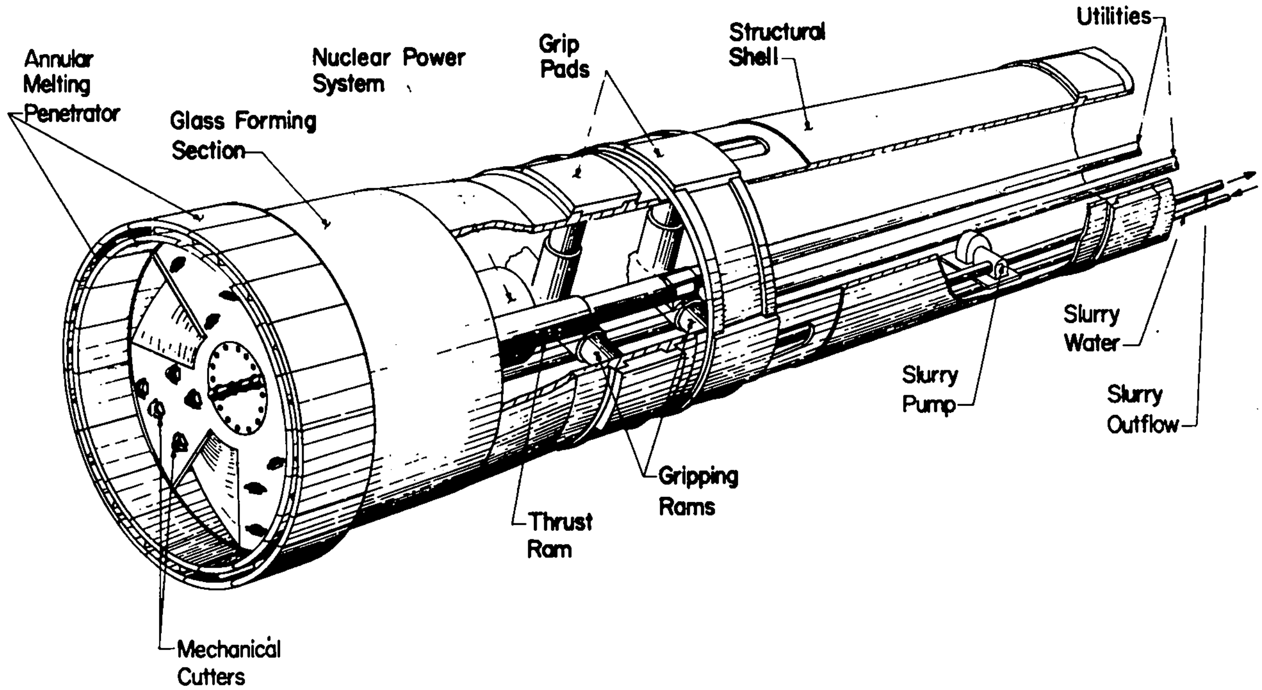


Fig. 1. Conceptual design of Type-I NSTM with peripheral kerf-melting penetrator and mechanical central-face cutter.

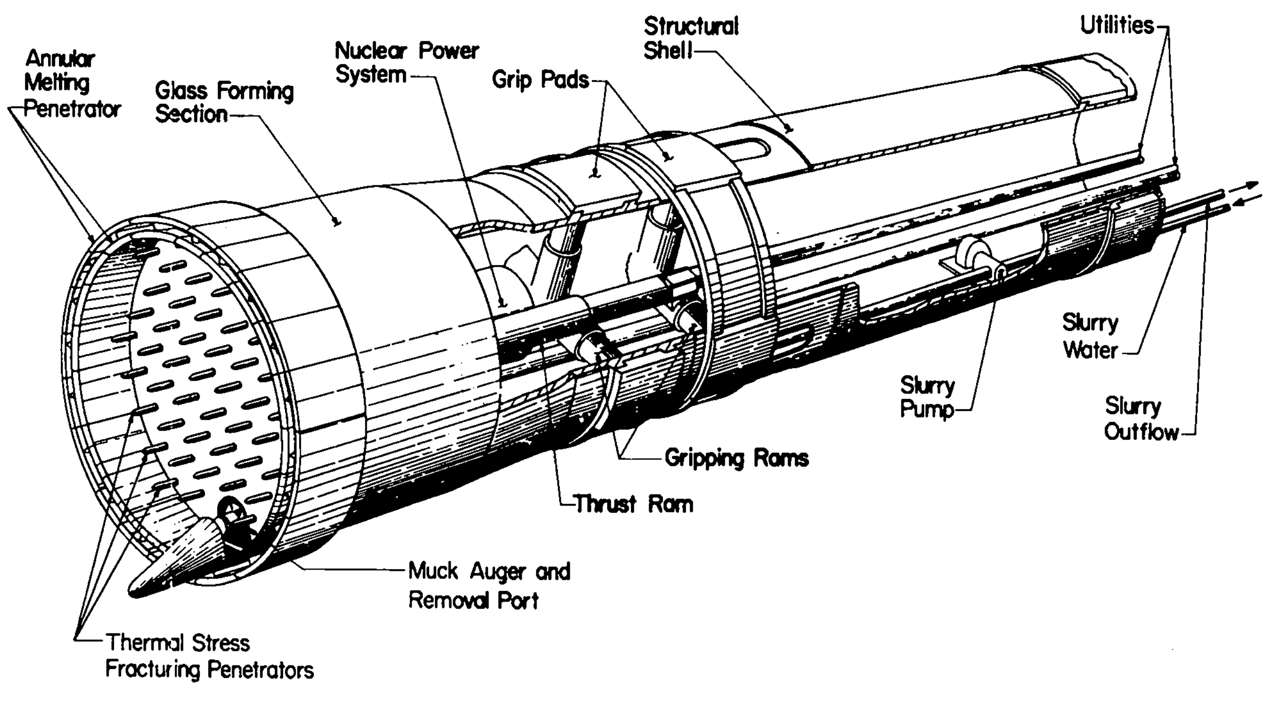


Fig. 2. Conceptual design of Type-II NSTM with peripheral kerf-melting penetrator and central-face thermal fracturing penetrators.

- Type II--uses a similar kerf-melting device, but the rotary cutters are replaced by an array of hot penetrators which thermally crack and fragment the rock at the working face. This concept is applicable to very hard rock.

The important advantages in soft-ground tunneling of the Type-I NSTM concept have been emphasized by Hanold.[7] The potential ability of the peripheral kerf melter to continuously seal, stabilize, and support the soil of the tunnel wall immediately behind the NSTM as the tunnel hole is formed is a major breakthrough in tunneling technology. However, the kerf-melting penetrator designs are not limited to the annular, extended-surface types illustrated; this is discussed later in the text.

D. Future Study Plans

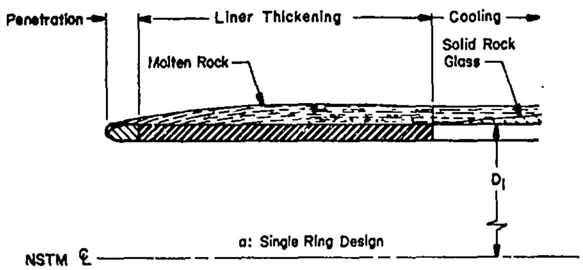
The NSTM design and economic models, and cost evaluations, will be expanded and refined as experimental data and firmer design data become available. The General Research Corp. computer program[8] for estimating excavation costs is being acquired and is expected to be especially useful for obtaining TBM and conventional costs. To provide an increasingly realistic NSTM cost model, more information will be required in the fields of rock-glass liner formation and structural characteristics; reactor design; nuclear fuel; heat pipes; heat-distribution losses; component lifetimes and reliabilities; tunnel advance rates; assembly, maintenance, and diassembly cycles; and the ability of the NSTM to accommodate wide geological variations. Tradeoff studies will be made between important parameters in the excavation, materials handling, and support operations; and labor, equipment, and materials cost estimates will be refined. Excavation demand information will be updated as data from a broader base become available from a projected U.S. tunneling-demand survey by the National Academy of Sciences - National Academy of Engineering.[9]

II. DESCRIPTION OF NSTM SYSTEM ANALYZED

A. Summary of Assumptions and Subsystem Choices

The following is a brief list of assumptions and subsystems that were chosen to facilitate the preliminary cost analysis for large-diameter tunnel construction projects using the two conceptual types of NSTMs shown in Figs. 1 and 2:

- The NSTMs are peripheral kerf-melting types.
- NSTM tunneling costs are compared to costs accrued by using TBMs and conventional methods only, for both rock and soft ground. Cut-and-cover and immersed-tube methods were not considered.
- Tunnel sizes studied range from about 4-to 12-m finished diameter.
- Tunnel cross-section configurations for the NSTM are not restricted. However, for calculational convenience, circular cross sections are used.
- The NSTM average operational sustained advance rate is 0.423 mm/s = 1.5 m/h, which is equal to 36.5 m/day (≈ 120 ft/day ≈ 5 ft/h).
- Thermal energy for rock melting is obtained from a nuclear reactor system installed in the NSTM.
- Liquid-metal heat pipes are used to transfer heat from the reactor core to a heat reservoir and then to the rock-melting penetrators.
- The NSTM-generated glass tunnel liner is strong enough to eliminate the need for any other form of temporary support. The liner thickness is 4% of the finished tunnel diameter (~ 0.5 in. per foot of tunnel diameter) for unfavorable conditions and is 2% of finished tunnel diameter for very hard rock (e.g., basalt).
- The permanent tunnel liner consists of the glass plus a usual concrete liner, with overall thickness equaling 8% of the tunnel diameter for all earth and rock conditions.
- Because the temporary glass liner is a structurally sound tunnel support there is no need for rapidly installing a permanent liner. Therefore, the tunnel contractor is free to either choose the most economical liner schedule or to employ an innovative continuous concrete liner process such as the Extruded Liner System described by Parker and Semple of the University of Illinois.[10]
- The rock-melt glass liner, reactor containment structure, cutter drive motor, tunnel air, etc., are water-cooled.



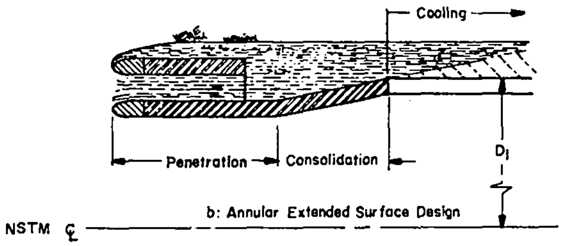


Fig. 3. Two types of kerf-melting penetrator designs.

- Closed-loop cooling-water circuits are used, with filtering and cooling accomplished at the tunnel portal.
- Electric power for other than rock-melting use is generated at the portal utilizing heat scavenged from the cooling water.
- The excavation face is sealed by a peripheral seal and a face structural diaphragm.
- Muck removal is by the hydraulic-slurry method using muck lines which penetrate the face diaphragm.
- Utility lines are continuously extended to accommodate NSTM advance by means of a trailing-line extender assembly.
- A manned control center is located in the tunnel as a component at the aft end of the NSTM.

B. Technical Description of Major Subsystems and Their Operation

1. Kerf Penetrator

Two types of kerf penetrator bit subsystems could be considered, as illustrated in Fig. 3. The single-ring penetrator, Fig. 3a, is (1) structurally simple, (2) requires a long, trailing kerf-melting section to develop a thick kerf liner, and (3) is most applicable in very sound rock requiring only a thin peripheral liner. The characteristics of the annular, extended-surface arrangement, Fig. 3b, are: (1) heat flow to the outside wall can be minimized to just allow the machine to move through rock at the desired rate, (2) heat flow can be maximized to the annular space where heat losses to surrounding rock can be minimized, and (3) the extended heat-transfer surfaces result in a higher permissible advance rate when thick liners are being considered. The annular, extended-surface type was chosen for calculating power requirements for this report. Both kerf-penetrator system designs need further detailed study and other design concepts will undoubtedly emerge as the technology develops.

2. Nuclear Subsystem and Power Requirements

The nuclear subsystem will be completely sealed and will include heavy biological radiation shielding and a massive, armored shell. Heat will be transferred through the shielding and armor by heat pipes into a heat-distribution reservoir. Control rods will be actuated by water-cooled electric actuators. The reactor will operate at relatively low internal core pressure and the shielding, containment, and armor walls will be protected by water-cooling. The nuclear subsystem will be replaceable, if necessary, in case of a malfunction. Fuel life is estimated at 9000 h while the remainder of the system will have at least a lifetime of 90000 h.

To obtain an estimate of thermal power requirements, the thermal properties of typical tuff and basalt materials[11] were used with the following properties, conditions, nomenclature, and units:

	Symbol	Tuff	Basalt
Rock density, kg/m^3	ρ_i	1400	2800
Rock glass density, kg/m^3	ρ_g	2600	2800
Specific heat, J/kg K	c	1000	1000
Heat of fusion, J/kg	ΔH_L	418×10^3	418×10^3
Melting temperature, K	T_m	≈ 1470	≈ 1420
In-situ temperature, K	T_i	290	290
Average melt temperature, K	T_{avg}	1570	1570

Tunnel finished inside diameter	D, m
Glass liner inside diameter	D_i, m
Glass liner outside diameter	D_o, m
Glass liner thickness	$t_\ell = \dfrac{(D_o - D_i)}{2}$, m

Average advance rate	V, m/s
Glass liner cross sectional area	A_g, m^2
Useful heat flow rate into the rock	$\dot{E}_{use}$, MW
Total reactor thermal power	$\dot{E}_{total}$, MW

The glass lining thickness needed to provide safe temporary support is a function of the specific project. Considerations of liner thickness may include such variables as overburden pressure, type of ground, water flow, geologic consistency, and tendency to swell. Due to these imponderables, tunnel designers have used empirical rules that are apparently conservative enough to have withstood the test of time. According to one such rule, the permanent concrete lining should have a thickness of 80 mm/m (1 in./ft) of tunnel diameter.[12] For a temporary liner thickness, using glass, it was assumed for this study that a thickness equal to $\sim$ 40 mm/m of tunnel diameter (0.5 in./ft $\cong$ 0.04 x D) would be adequate in unfavorable ground and that 20 mm/m of diameter (0.25 in./ft $\cong$ 0.02 x D) would apply for favorable RQD conditions.* Then, using (0.04 x D) as the lining thickness, the diameter and glass liner cross-sectional area relationships applicable to soft rock or ground are:

$$D_o = D + 2\ (0.08\ D)$$

$$D_i = D + 2\ (0.04\ D)$$

$$A_g = \frac{\pi}{4}\ (D_o^{\ 2} - D_i^{\ 2}) = 0.1407\ D^2.$$

Solving for $\dot{E}_{use}$, the power required is:

$$\dot{E}_{use} = A_g\ V\ \rho_g\ C\ (T_{avg} - T_i) + A_g\ \rho_g\ \Delta H_L$$

and, using the tuff properties previously defined,

$$\dot{E}_{use} = 620\ D^2\ V,\ MJ/s \equiv MW.$$

The various losses of thermal power which could occur around the peripheral kerf penetrator bits were estimated and are shown in Fig. 4, itemized in Table I, and further illustrated in Fig. 5a. Then, including losses equal to 40%, the thermal total power source required is:

*The RQD (Rock Quality Designation) is a rating scale of rock quality introduced by D. U. Deere[13] and is based on specific geologic factors as observed during analysis of core samples.

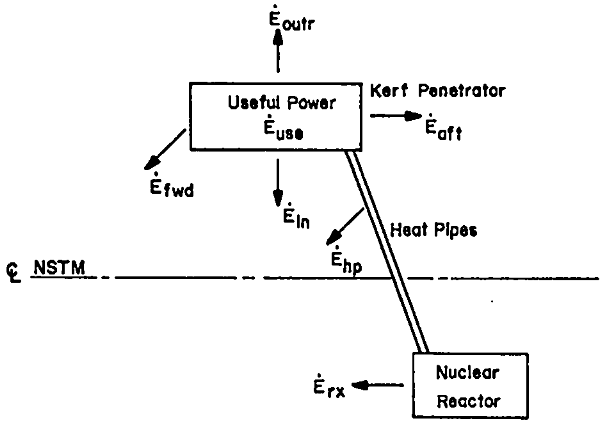


Fig. 4. Schematic of heat fluxes related to penetrator, heat pipes, and reactor subsystems.

$$\dot{E}_{total} = \frac{\dot{E}_{use}}{0.6}\ D^2\ V = 1030 \times D^2\ V,\ MW.$$

The above power requirement is shown graphically in Fig. 6 for an advance rate V = 0.423 mm/s (5 ft/h). This advance rate is equal to that already achieved during small-scale penetration tests.[6] The goal of the current Subterrene project is a target advance rate for the NSTM of 1.0 mm/s (11.8 ft/h = 283 ft/day).

The loss to the surrounding rock around the penetrator (Table I) is estimated to be 20% of $\dot{E}_{total}$. As will be shown later, another 21% will be lost to the rock during the glass liner cooling process, making a total of 41% of $\dot{E}_{total}$. This radial dissipation of power will not heat the rock to any

TABLE I

ESTIMATED PERIPHERAL KERF-MELTING PENETRATOR SYSTEM AND REACTOR HEAT LOSSES

Heat Loss Contribution	Symbol	Estimated Fraction of Total Reactor Power
Loss forward and inward into rock face	$\dot{E}_{fwd}$	0.01
Radial outward heat-flow loss into surrounding rock	$\dot{E}_{outr}$	0.20
Loss aft into cooler machine structure	$\dot{E}_{aft}$	0.10
Loss radially inward	$\dot{E}_{in}$	0.01
Loss from heat pipes	$\dot{E}_{hp}$	0.04
Losses to reactor containment	$\dot{E}_{rx}$	0.04
Total Fraction of Losses		0.40

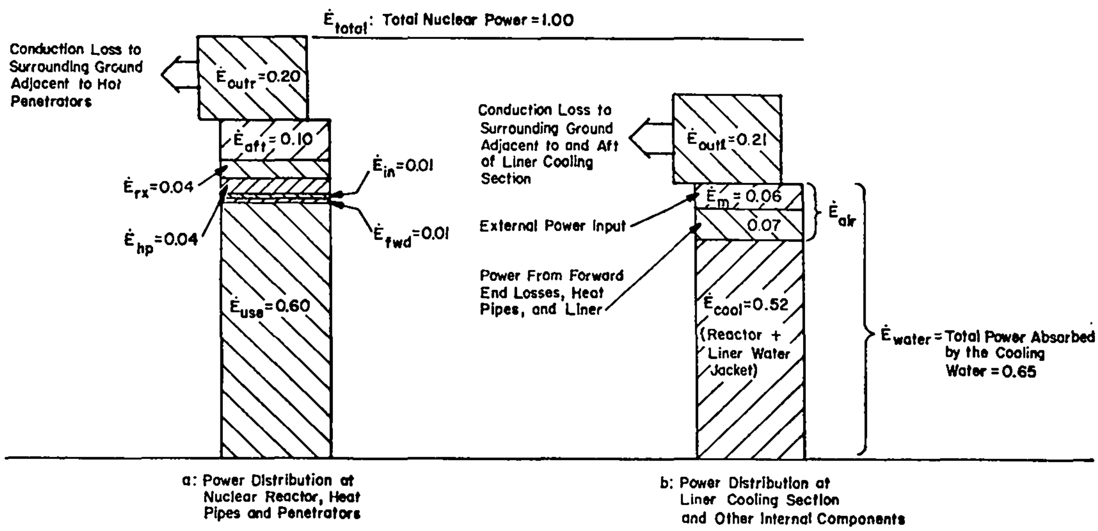


Fig. 5. Power distribution for a Type-I NSTM.

significant distance from the tunnel-liner outside diameter. To illustrate this point, consider the case of a 7.3-m tunnel in tuff with a reactor power output of 23.4 MW. The energy dissipated to the rock could be stored in a 1-m-thick annulus outside the tunnel liner, with the 1470-K rock-melting temperature at the inner radius and the 290-K rock in-situ temperature at the outer radius. In basalt, the above annular thickness would only be 0.5 m.

3. Face Removal

a. Type-I NSTM

The Type-I NSTM concept (see Fig. 1) uses a rotary cutter assembly to remove the face soil and rock inside the melted peripheral kerf. The rotary design is assumed to be similar to the cutters now being used in TBMs. However, the effectiveness and useful life of the cutter assembly in the NSTM is expected to be better than in a TBM. Carstens[14] has pointed out the generally accepted fact that the outside gage cutters, in comparison to the interior cutters, account for the greatest share of the total cutter cost, ranging from 30 to 60%. In the NSTM, the usual gage cutters and their problems will be eliminated completely, the peripheral rock being taken care of by the kerf-melting penetrators. In competent rock the kerf penetrator aids the cutters in two other ways. First, the rock in the peripheral area of the rotary cutter head is thermally spalled and cracked by the kerf penetrator. Second, this rock is subject to some heating and hence some lessening of strength. In loose soils a rotary head suitable for such strata will be used, operating in the significantly advantageous situation of a stabilized tunnel bore provided by the NSTM with its continuously formed glass lining.

The cutter drive motor will be located aft of the face-seal structural diaphragm and thus will be in a favorably clean environment. If necessary, the motor can be cooled by a line branching off of the main water-cooling system. Suitable entryways for

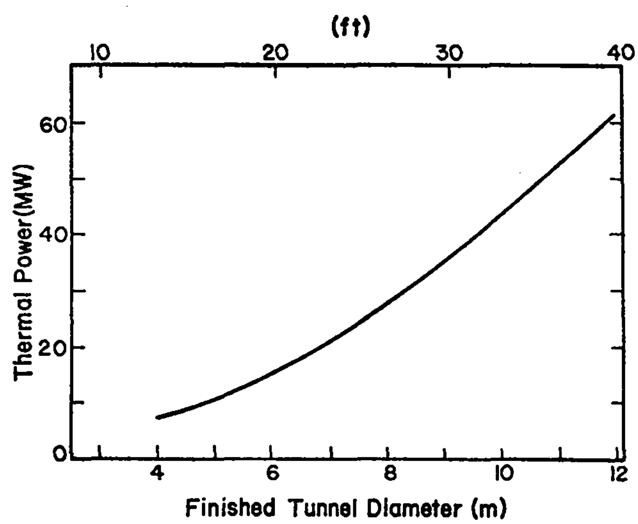


Fig. 6. Reactor thermal power vs finished tunnel diameter.

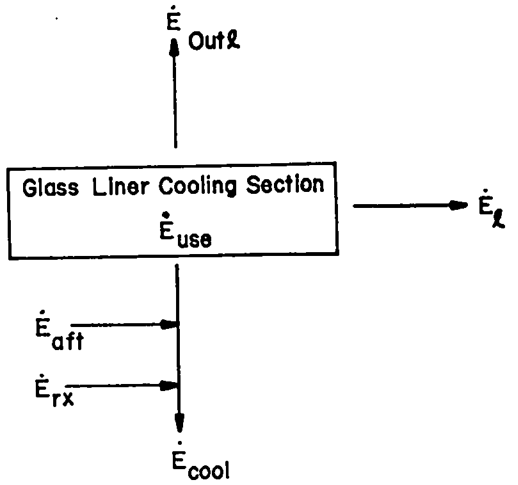


Fig. 7. Schematic of heat fluxes related to glass liner cooling section.

cutter removal or changes and general maintenance must be provided in the face seal structure.

b. Type-II NSTM

The Type-II concept (shown in Fig. 2) substitutes an array of spike-like rock-melting penetrators for the rotary cutters of the Type-I assembly. The Type-II concept is applicable to very hard rock, the rock being fragmented by thermal-stress fracturing. This design, while theoretically sound, still contains many yet-to-be resolved parameter optimizations, such as penetrator spacing, power, size of each penetrator, and adaptability to geologic variations.

The total rock penetration and fragmentation power for the Type-II NSTM, is assumed equal to that of a Type-I machine (see Fig. 6). Type-II in basalt and with a liner thickness equal to 0.02 D, requires a useful liner power, $\dot{E}_{use}$, equal to 0.55 $\dot{E}_{use}$ of Type-I in tuff. The remaining 0.45 power fraction is used for the spike penetrator bits and redistributed heat losses in the Type-II machine.

4. Glass Liner Cooling

The glass liner will be cooled in two ways. Liner heat will be dissipated radially outward into the surrounding rock and will also flow radially inward into the liner water-cooling system. The structural characteristics of the liner will be determined by the cooling process, from average rock-melt temperatures to about 900 K. If the NSTM were completely automated, high wall temperatures might be permissible at the aft end of the machine. However, water could be used to cool the wall down to about 305 K (90° F). Local refrigeration and cool air circulation systems installed inside the NSTM could provide adequate working conditions. Final wall-cooling could be accomplished by a water-cooled air circulation system as explained later. Considering only the heat absorbed by the water flowing through the reactor and the liner coolant jacket, $\dot{E}_{cool}$, five heat flows are involved, shown schematically in Fig. 7. Three, $\dot{E}_{use}$, $\dot{E}_{aft}$, and $\dot{E}_{rx}$, were defined previously and are equal to 0.60, 0.10, and 0.04 of $\dot{E}_{total}$, respectively. The other two heat flows are: $\dot{E}_{out\ell}$, the heat flow radially outward into the surrounding rock, and $\dot{E}_{\ell}$, which is residual heat in the glass liner after the liner water-cooling section has moved on. The quantities $\dot{E}_{out\ell}$ and $\dot{E}_{\ell}$ are estimated to be 0.21 $\dot{E}_{total}$ and 0.01 $\dot{E}_{total}$, respectively. Then, the water heat load from the liner and reactor is,

$$\begin{aligned}\dot{E}_{cool} &= \dot{E}_{use} + \dot{E}_{aft} + \dot{E}_{rx} - \dot{E}_{out\ell} - \dot{E}_{\ell}\\ &= (0.60 + 0.10 + 0.04 - 0.21 - 0.01)\ \dot{E}_{total}\\ &= 0.52\ \dot{E}_{total}.\end{aligned}$$

5. Air Cooling and Circulation

The air cooling and circulation subsystem is shown schematically in Fig. 8. This subsystem will cool the wall to a final low temperature by flowing air in direct contact with the wall. The air will also absorb heat generated in the forward sections of the NSTM, e.g., at the cutter drive motor or muck machinery and will provide for a reasonably low temperature inside the NSTM for personnel. The circulating air can be replenished as necessary by means of an air utility line from the portal. The circulating air, kept in motion by an electric-motor drive fan, is continuously cooled in a water-cooled heat exchanger.

6. Total Water Heat Load

It is estimated that the various machines within the NSTM generate a thermal power load, $\dot{E}_m$, equivalent to 0.06 $\dot{E}_{total}$. This amount -- added to estimated values for $\dot{E}_{fwd}$, $\dot{E}_{hp}$, $\dot{E}_{in}$, and $\dot{E}_{\ell}$ (the heat in the liner absorbed by the circulating air) --

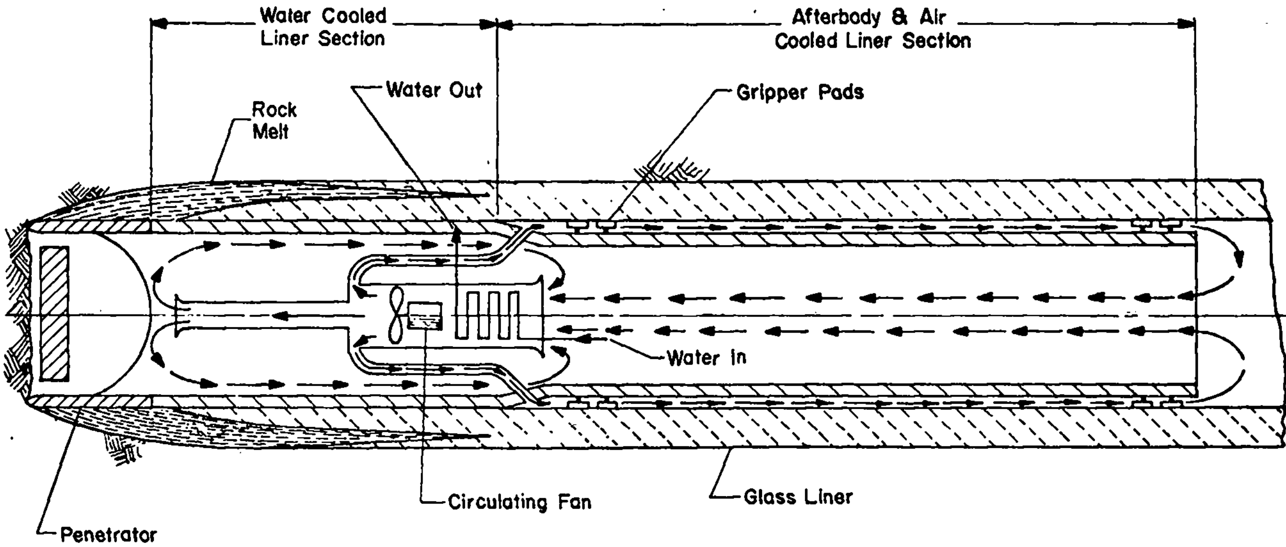


Fig. 8. Schematic of air cooling and circulation subsystems.

equals the total heat load absorbed by the cooling water in the air-circulating system and is called $\dot{E}_{air}$ (see Fig. 5b for an illustration of the above power distributions).

Then,

$$\dot{E}_{air} = \dot{E}_m + \dot{E}_{fwd} + \dot{E}_{hp} + \dot{E}_{in} + \dot{E}_\ell$$

$$= (0.06 + 0.01 + 0.04 + 0.01 + 0.01)\dot{E}_{total}$$

$$= 0.13\ \dot{E}_{total};$$

and, the total heat load into the cooling water is:

$$\dot{E}_{water} = \dot{E}_{cool} + \dot{E}_{air}$$

$$= (0.52 + 0.13)\ \dot{E}_{total}$$

$$= 0.65\ \dot{E}_{total}.$$

7. Hydraulic Slurry Muck Removal

Complementary to the water systems used for cooling the glass liner and the NSTM equipment, is the hydraulic slurry muck removal system. It is assumed that part of the cooling water can be diverted to fluidize the muck. In very favorable circumstances the resultant water outflow from the tunnel might be discarded and fresh water pumped in. However, for cost purposes, it is assumed that closed circuits are needed with only some makeup water supplied as necessary. At the portal, portable dry-cooling towers will reduce the water temperature to a level adequate for recycling. The water will also be filtered and cleansed before reuse. Some water-cooling circuits will be isolated from the muck-contaminated circuit to avoid fouling certain critical coolant-flow passages.

8. Portal Power Subsystem

As noted in Section II-B-6, above, the cooling water returning to the portal carries heat equivalent to about 65% of the reactor heat release. Most of this heat will be dissipated through the cooling towers emplaced at the portal. However, it is also assumed that a portal power subsystem (PPS), extracting energy from the cooling water, will generate the electricity needed for NSTM components other than the penetrators. This power will be obtained with an organic Rankine-cycle power system because of the relatively low water temperatures available. Power generation and water cooling can be done, e.g., with subsystems illustrated in Fig. 9.

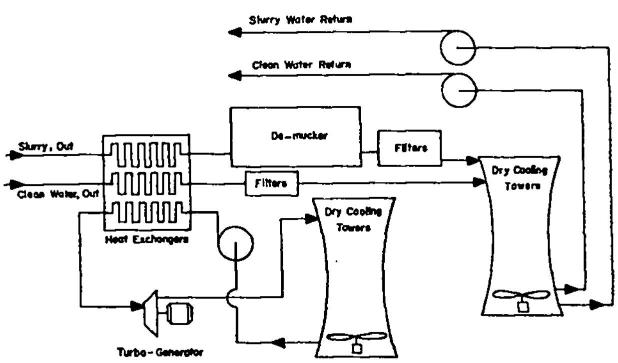


Fig. 9. Schematic of portal power and cooling subsystems.

Thus, except for startup, shutdown, emergency, and other miscellaneous power requirements, most of the NSTM operation could be approximately sustained solely by the nuclear reactor power.

9. Sealed Excavation Face

The NSTM system with its close fit around the kerf penetrators and the glass liner cooling section is ideally suited to a sealed and pressurized working-face operation. Thus, the problems of water and gas inflow into the tunnel, except in extreme cases, are eliminated when the machine is operating. Minimal leakage would normally be expected through the glass-lined walls aft of the penetrators. To further improve the face seal, a peripheral sealing device could be easily incorporated. A diaphragm bulkhead structure could be used to seal the central face area. The only operational openings would be those used to feed the muck into the slurry crushers and grinders for subsequent pumping to the portal for disposal, and access to the rotary cutter head for maintenance and cutter changes.

10. Thrusters, Grippers, and Guidance

As projected in Figs. 1 and 2, the main structural component of an NSTM is a cylindrical shell housing the various subsystems. Thruster-actuators push axially on the main cylindrical structure and react against radially expanding gripper pads. Two sets of gripper pads are located at forward and aft stations, respectively. One set of each pair can be gripping while the other shifts forward to take a new advance position. Machine guidance is possible by adjusting the radial extension of the various gripper pads. It is assumed that only very gradual changes in direction will be required with the types of NSTMs studied. Hydraulic actuators can be used because of the low temperatures inside the NSTM. The system is basically that in use for most TBMs.

11. Utility Lines and In-Tunnel Transportation

The main water-cooling lines have already been described. Other general-purpose utility lines will be required for such needs as fresh air, auxiliary power, and communications. For extension of all lines that cannot be unreeled conveniently, it is projected that a line-extender assembly will be mounted on a trailer towed behind the NSTM. Because of the smoothness of the glass-lined tunnel walls and floor either railed or wheeled vehicles can be used.

12. Control Center

A fully instrumented, cooled, control center mounted at the aft end of the NSTM is anticipated, from which the reactor and heat-transmission operation as well as the various other excavation processes can be manually monitored.

III. COST ANALYSIS

A. NSTM Cost Estimates

The two initial designs of NSTM systems described in Section II were used for cost estimating purposes. One general economic characteristic of the NSTM system is the fact that it is much more capital-intensive than conventional and TBM excavation equipment. Whereas, in past excavation projects, it was customary to write off a tunneling machine after a single project; much of the equipment for NSTM excavation systems will be used until its operational lifetime will have been reached. Fortunately, costly Subterrene components are not exposed to the harsh conditions that components in, e.g., TBMs have to endure. For example, the nuclear energy system in the NSTM will be completely enclosed and contained. Similarly, the heat pipes will be enclosed. Also, dust and debris will be contained in the forward face cavity of the NSTM, and trailing equipment and utility lines will encounter only relatively clean and smooth glass-lined tunnel walls. However, certain components, e.g., rotary cutter assemblies, rock grinders, and crushers in the hydraulic slurry disposal system, will still be limited to more traditional operating lifetimes.

With NSTMs, the tunneling contractor will be faced with higher capital investments than with conventional equipment; i.e., the cost of capital will increase and must be accounted for in the overall cost of a tunneling project. A firm might raise capital by various means, e.g., by selling stocks or bonds, drawing on reserves, or taking a loan.[15] To arrive at a cost-of-capital effect on overall cost in a simple manner the procedure presented in the following discussion was used.

For the basic equipment-cost estimations the NSTM was categorized by identifying basic subsystems, and operational lifetimes were assigned to each. The estimated capital cost of each subsystem was amortized over time periods of approximately

TABLE II

EXAMPLE OF TYPE-I NSTM EQUIPMENT COSTS, 7.3-m (24-ft) DIAMETER, 23.4-MW POWER
(Costs Based Upon 1972 Dollars)

NSTM Subsystem	Lifetimes: Amortization, yr	Lifetimes: Actual, h	Capital Cost, M$	8% Interest on Remainder, M$	Salvage Value, M$	Cumulative Cost, M$	Cost per Advance (V=1.523 m/h), $/m	Cost per Advance (V=5 ft/h), $/ft
Kerf penetrators	1	4500	1.500	0.120	(0.150)	1.470	214.3	65.3
Mechanical cutters	1	4500	0.800	0.064	---	0.864	126.0	38.4
Slurry grinder, pumps, and pipes	1	4500	0.150	0.012	---	0.162	23.6	7.2
Liner cooling surface	1	4500	0.750	0.060	(0.075)	0.735	107.2	32.7
Nuclear fuel	2	9000	0.702	0.085	---	0.787	57.4	17.5
Heat pipes	5	20000	0.300	0.076	(0.030)	0.346	11.3	3.5
Mechanical cutter drive	5	20000	0.200	0.050	---	0.250	8.2	2.5
Nuclear system less fuel	20	90000	4.194	4.349	---	8.543	62.3	19.0
Water coolant system	20	90000	0.150	0.156	(0.015)	0.291	2.1	0.6
Air circulating system	20	90000	0.150	0.156	(0.015)	0.291	2.1	0.6
Thruster and grippers	20	90000	0.100	0.104	---	0.204	1.5	0.4
Control center	20	90000	0.250	0.259	---	0.509	3.7	1.1
		Subtotal	9.246	5.491	(0.285)	14.452	619.7	188.8
Air, power, and water utility lines	1	4500	0.100	0.008	---	0.108	15.7	4.8
Portal power and cooling	20	90000	1.300	1.348	(0.130)	2.518	18.4	5.6
		Subtotal	1.400	1.356	(0.130)	2.626	34.1	10.4
		Total	10.646	6.847	(0.415)	17.078	653.8	199.2
Totals Referred to 1969 Dollars [16]			9.339	6.006	(0.364)	14.981	573.5	174.7

twice the operational life of the subsystems; i.e., the actual use-to-calendar time ratio is 0.50. Capital-equipment funds were borrowed with interest charges of 8% of remaining capital, paid off over the various amortization periods. Certain components made of relatively expensive materials were assigned a 10% salvage value. These include kerf-melting penetrator slabs, heat pipes, glass-liner cooling surface slabs, water-cooling jacket, air circulating system located in the NSTM, and the portal power and water-cooling systems. Finally, costs in dollars per tunnel length were calculated by assuming an average NSTM advance rate of 0.423 mm/s (5 ft/h). Table II summarizes typical estimated costs for a Type-I NSTM (kerf-melting plus mechanical cutter) designed to produce a tunnel with a finished diameter of 7.3 m (24 ft) at a nuclear power level of 23.4 MW (thermal power). These estimates are referred to 1972 dollars. To refer to 1969 dollars, an overall inflation factor of 14% is used from 1969 to 1972.* The inflation rate for the excavation equipment analyzed might very well be considerably higher, but this effect was not studied. Summary total equipment cost in 1969 dollars for

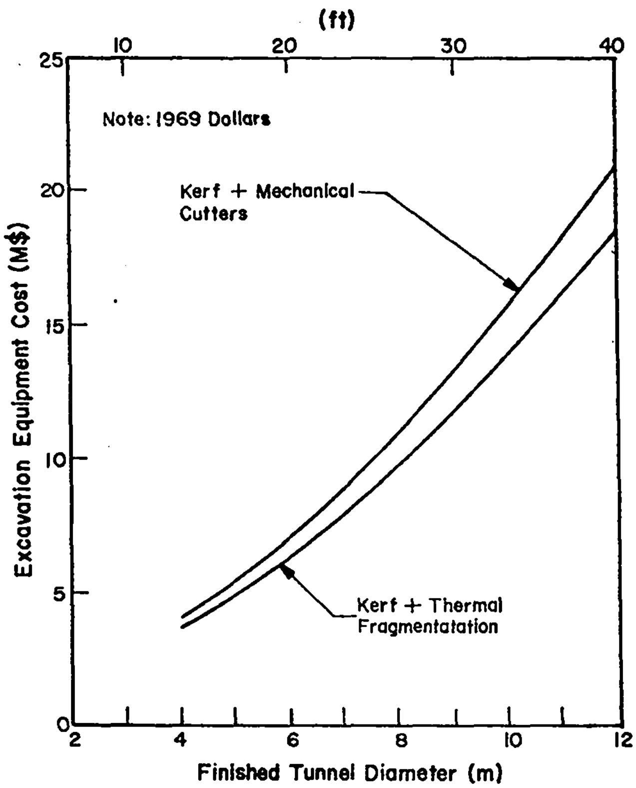


Fig. 10. NSTM excavation equipment costs vs finished tunnel diameter.

*Overall national inflation rate for that period as published by the U.S. Department of Commerce.[16]

TABLE III

BASES FOR EQUIPMENT COST AND LIFETIME ESTIMATES

Item	Basis
1. Heat pipes and penetrators	LASL experience since 1963. Conservative assumptions: lithium/molybdenum pipes at 200-to 400-MW/m^2 capacity. Penetrator costs based on use of molybdenum, tungsten, and other refractory parts at average cost of 22 \$/kg (10 \$/lb).
2. Nuclear components	High-temperature gas-reactor electric utility costs[17] multiplied by factor of 6 to allow for compact size needed for NSTM. NSTM reactor equipment costs are \$180/kW and fuel costs are 3.35 mills/kWh, both based on thermal power (not electric) and on 1972 dollars.
3. Mechanical cutter	Tunneling machine costs per Ref. 14 range from \$250,200 to \$1,225,000 in 1969 \$, the latter value being for a 21-ft-diam tunnel. For this study, a baseline 7.3-m-(24-ft-) diam machine cost of \$1,000,000 (1972 \$) was selected to cover cost of cutter wheel and structural mount, with \$200,000 included for the drive motor.
4. Muck removal	Costs given by Holmes and Narver, Inc.[18] and those derived from COHART[19] for current conveyor systems were studied. It was concluded that the COHART costs could be conveniently used to represent future slurry systems without affecting the overall results significantly.
5. Portal power and cooling	Power-industry-type costs were used conservatively enough to cover additional costs for a mobile system and setup. Typical costs of turbine and electric equipment are 66 to 84 \$/kW, based on 1973 dollars.[17]
6. Control center	A cost of \$250,000 was assumed for all sizes using similar electronics. This compares with \$150,000 for completely automated controls for the LASL 370-MW nuclear space engine.
7. Other components	Because many miscellaneous smaller components were not detailed and their cost effects were obviously small, order-of-magnitude estimates only were made.
8. Operating lifetimes	For the penetrators, mechanical cutters, slurry components, liner cooling surfaces, and utility lines, a lifetime of 4500 h was estimated for future components considering the relatively favorable NSTM environment.
	For the hot penetrating surfaces, a 4500-h lifetime was deemed feasible. This is indicated by small-scale LASL tests where, under very harsh conditions, a maximum hot-wall erosion rate of 13 μm/h (0.0005 in./h) was measured.
	For the nuclear fuel, a 9000-h period between refueling operations is consistent with nuclear power-plant practice.
	High-temperature heat pipes have been operated well over 10,000 h, and a doubling of their lives to 20,000 h is not considered too difficult.
	Electric utility practice assumes a 30-year lifetime with some maintenance. The long-lived components in this study were assumed to have a lifetime of only 10 years.
9. Scaling procedures	Scaling on size from a 7.3-m-diam tunnel baseline was done by assuming that costs varied with the square of the tunnel diameter except for the nuclear system for which a square-root relationship was used. As noted earlier, control-center costs remained fixed.

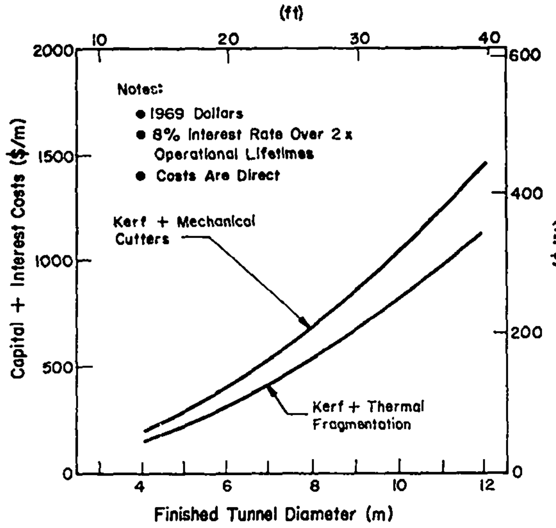


Fig. 11. NSTM excavation equipment plus interest costs per unit tunnel length vs finished tunnel diameter.

the two types of NSTM systems are plotted in Fig. 10, and Fig. 11 displays similar data in a cost-per-unit tunneling length basis.

Table III lists the bases for the cost estimates used to establish the values summarized in Table II. In general, very conservative estimates were made for all nonconventional subcomponents of the NSTM. However, the experience in refractory-metal material and fabricating costs gained thus far in the project was factored into these estimates. The subcomponents that are based upon conventional equipment technology were costed by using existing data for such equipment as extensively as possible.

Direct NSTM operating costs were estimated by using data derived from the COHART computer program for conventional and machine costs (based upon 1969 dollars)* as a base to arrive at reasonable conventional or TBM-type direct cost items and adjusting these values for NSTM costs. These COHART data were supplied by Foster.[19] Tables IV and V summarize typical results of these operating-cost estimates. The tables show the percentage contribution to the total in each case of the major project processes: excavation, materials handling, and supports, as well as labor, equipment, and materials distribution. It can be seen that the cost distribution for NSTMs is markedly different from conventional or TBM costs;

*The cost reference base was chosen as 1969 dollars because the COHART program data base utilized this reference.

TABLE IV

TYPICAL COST DISTRIBUTION FOR MAJOR EXCAVATION ELEMENTS OF A 7.3-m-(24-ft-) DIAMETER TUNNEL

Earth Conditions	Type Machine	% of Total Project Costs: Excavation	Materials Handling	Support and Liners
Medium rock	Type-I, NSTM	48	31	21
Hard rock	Type-II, NSTM	43	32	25
Medium rock	TBM	38	30	32
Soft ground, Variable	Type-I, NSTM	47	22	31
Soft ground, dry	TBM	19	23	58

for the NSTM a greater cost percentage is concerned with excavation and less with supports and liners. This difference is ascribed to higher NSTM excavation equipment costs and to associated lower costs for liners and supports.

The COHART data were available as raw direct costs to which factors had to be applied to account for profit, overhead, and regional cost effects. According to Wheby and Cikenek[20] the computer data are based on 1969 dollars and on Chicago prices. By referring to pertinent mid-1969 issues of the Engineering News Record (ENR) publications with data available for prices in 22 major U.S. cities, it was estimated that for typical tunneling projects the cost index used in COHART, based on arithmetic averages for the 22 cities, is about 5% less than for Chicago only. Therefore, an approximate cost index of 1.00 was deemed satisfactory.

For regional factors (which take into account, e.g., labor union regulations, militancy, and other costly restrictions), Wheby and Cikenek present a scale ranging from 1.0 to 3.0 with 1.1 applying over much of the U.S. They list a factor of 1.5 for the Northeast Corridor, excluding New York City. In this study, a factor of 1.3 was estimated to apply to overall U.S. tunnel projects.

TABLE V

TYPICAL PROJECT COST DISTRIBUTION BY LABOR, EQUIPMENT, AND MATERIALS FOR A 7.3-m-(24-ft-) DIAMETER TUNNEL

Earth Conditions	Type Machine	% of Total Cost: Labor	Equipment	Materials
Medium rock	Type-I, NSTM	42	42	16
Hard rock	Type-II, NSTM	44	37	19
Medium rock	TBM	51	21	28
Soft ground, Variable	Type-I, NSTM	33	49	18
Soft ground, dry	TBM	43	16	41

TABLE VI

COST FACTORS APPLIED TO NSTM AND COHART DIRECT COSTS TO ARRIVE AT NATIONAL AVERAGE COSTS

	NSTM	COHART
Cost index	1.00	1.00
Profit	1.06	1.09
Overhead	1.27	1.27
Regional	1.30	1.30
Net	1.75	1.80

A 27% overhead rate and a 9% profit are recommended in Ref. 20. In the NSTM case, for which the large equipment capital costs are assumed to consist of borrowed capital plus 8% interest, a contractor profit of 6% was allowed.

The factors applied to the COHART data are summarized in Table VI.

B. Comparisons With Conventional and TBM Costs

Data on conventional and machine-tunneling costs were compiled for comparison with Subterrene costs. Although the cost spread is broad and the desired consistency of the data is sometimes difficult to obtain, the general magnitudes and trends of these costs were identified.

Costs versus tunnel-diameter data for rock tunnels are shown in Fig. 12. The three curves designated (1) were taken directly from Spittel et al.[21] and represent equations and estimations from actual tunnel data. The sensitivity to type of geology is represented by RQD (Rock Quality Designation)[13] values from 100 down to 25%. Two variables that were not taken into account by Spittel are rock strength and abrasiveness. Their effect on the estimates is not clear because rock with an RQD = 100% is not necessarily very hard or abrasive. To more clearly define cost characteristics of cutters, rock strength and/or abrasiveness should be considered. Data designated (2) for conventional excavation were extrapolated from Baker et al.[1] by taking lower-bound excavation-only costs and then dividing by 0.35 to obtain approximate total costs.

Data denoted by (4) were estimated from COHART program data.[19] It was assumed that these data were representative of medium-strength rock, i.e., rocks with an average compressive strength of 135 MN/m^2 (20000 lbf/in.^{2}). Carstens[14] concluded on the basis of actual cost data that rock compressive strength was the best readily available parameter for correlating cutter costs. Using factors estimated from Ref. 14, the data denoted (4) were scaled up to the two curves marked σ = 275 MN/m^2 (40000 lbf/in.^{2}) and σ = 345 MN/m^2 (50000 lbf/in.^{2}) to arrive at an estimate of the significant additional costs which occur due to increased cutter wear in very hard rock. These latter curves are designated (3).

If we compare the NSTM data with the other data in Fig. 12, we see the following: At RQDs of 75 and 100%, the cost curves denoted (1) are significantly lower than those for the NSTM. However, for less favorable rock conditions, e.g. RQD = 25%, the NSTM is competitive and even a little superior. It has already been noted that the data plotted as (1) did

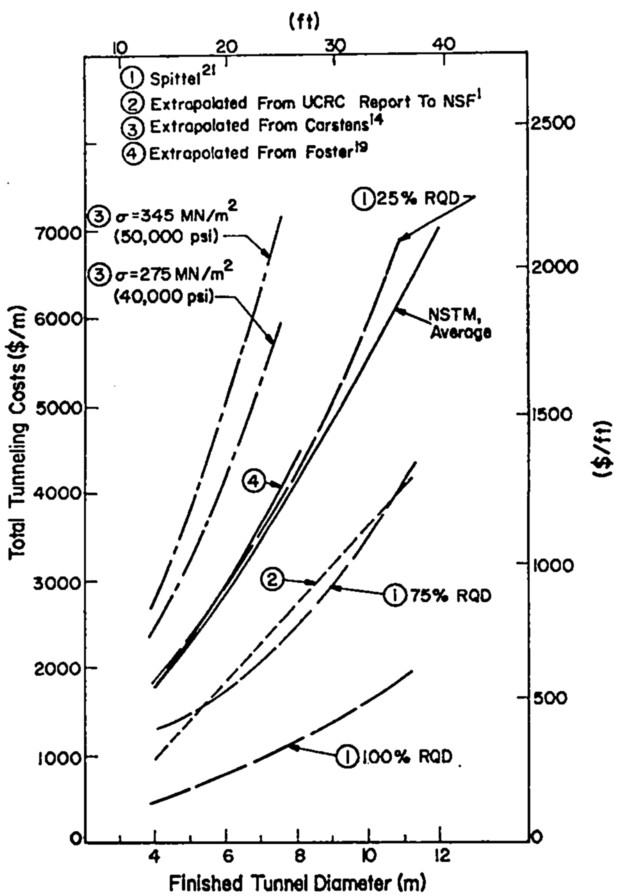


Fig. 12. Costs vs tunnel diameter for rock tunnels.

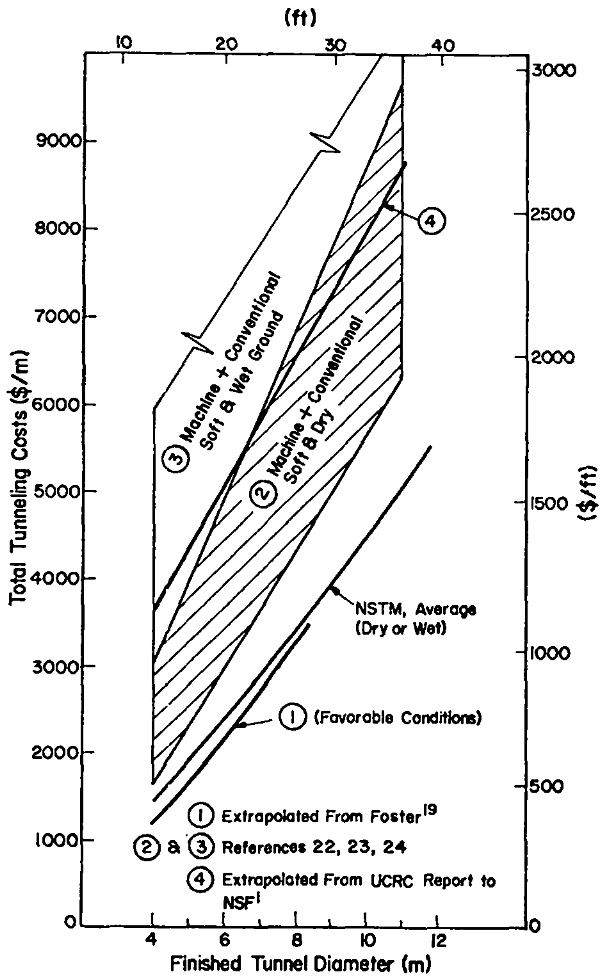


Fig. 13. Costs vs tunnel diameter for soft-ground tunnels.

not consider rock strength or abrasiveness as variables and that the effect of these rather important cost parameters is somewhat hidden. Nevertheless, the data for RQDs of 75 and 100% show that, at this stage of the economic evaluation, there are undoubtedly some projects in very favorable rock conditions where other simpler and more traditional techniques will compete with the currently projected NSTM systems.

However, the advantages of NSTMs become important if we consider very hard rock, i.e., with compressive strengths of 200 to 345 MN/m^2 (30,000 to 50,000 psi). For example, at a tunnel diameter of 7 m (23 ft) and at rock strengths of 275 and 345 MN/m^2, the NSTM costs would be 66 and 54%, respectively, of those resulting from a rotating cutter machine. The cost effectiveness becomes gradually even better as tunnel size increases.

The NSTM compares unfavorably to the costs labeled (2), which are minimum costs in rock using conventional methods and are based on actual data. However, for urban usage, the NSTMs would have important practical advantages because they would avoid the environmental problems caused by drill-and-blast techniques.

Fig. 13 shows cost data for soft-ground excavation. Data labeled (1) are estimated from the COHART computer program.[19] The data designated (2) and (3) summarize actual data for both conventional and machine techniques and were extracted from OECD, Fenix and Scisson, A. D. Little, and Virginia Department of Highway sources.[22,23,24]

The lower bounded data (2) are for soft, dry ground with the data above labeled (3) being for soft, wet ground. The spread of these data illustrates the strong influence of geologic variations on costs. It also illustrates the need for the development of new equipment that is less sensitive to the often encountered, but not necessarily anticipated, geologic variations. Data (4) are extrapolated from the UCRC report to NSF[1] and seem to correlate well with (2) and (3). These values were obtained by dividing Ref. 1 data, for the excavation process only, by 0.35 to obtain overall tunnel costs.

Comments pertinent to the comparison of NSTM costs with the soft-ground cost data shown in Fig. 13 are as follows. The NSTM estimates are nearly identical to the COHART estimates, Curve (1). However, both estimates fall far below historical data, Curves (2), (3), and (4). These indicate that tunneling problems, e.g., geologic variations, are perhaps not correctly anticipated by COHART. If we were to assume an additional multiplying factor to account for unanticipated earth conditions, the COHART data should be higher than the NSTM costs. The NSTM estimate shown is meant to cover both soft, wet, running, bouldery ground as well as soft, dry conditions and, thus, already discounts geological variations. Roughly, it appears conservative to conclude that the NSTM would reduce average soft-ground tunnel costs by ~ 50%.

TABLE VII

COST CONTRIBUTION OF THERMAL ENERGY ON A DIRECT COST BASIS

(1969 Dollars)

Type Ground & NSTM	4.1-m-diam Tunnel Total Cost, $/m	Fuel + System Cost, $/m	Thermal Energy Cost, %	10.7-m-diam Tunnel Total Cost, $/m	Fuel + System Cost, $/m	Thermal Energy Cost, %
Rock, Type I	1040	46.7	4.5	3460	188	5.4
Hard Rock, Type II	1020	46.7	4.6	3380	188	5.6
Soft Ground, Type I	810	46.7	5.7	2800	188	6.7

C. Energy Costs and Refueling Considerations

The thermal energy for penetrating rock for both Type-I and Type-II NSTMs was considered to be the same. For the kerf-and-mechanical cutter case (Type-I) all the energy is used to develop a thick temporary liner. Where the kerf-and-thermal fragmentation penetrators (Type-II) would be used, the rock conditions would be such as to require less liner thickness. Thus, the thermal energy to the kerf penetrators would be reduced and the energy saved would be diverted to the thermal fragmentation penetrators in the central-face area.

The nuclear fuel costs used in this report include the external costs of refueling. It was assumed that specialized nuclear reactor industries would handle all nuclear-related aspects of the excavation project. This would include reactor system manufacture, installation, on-the-job operation, maintenance, safety, and long-distance transportation.

No attempt was made to detail cost effects of recovering some thermal energy from the cooling water so as to generate electricity for running the slurry pumps, air circulating fans, cutter drive motors, etc.

Table VII summarizes the contribution of the costs of the nuclear fuel plus the nuclear subsystem needed to convert the fuel into thermal energy. On a basis of percentage of overall tunneling costs, the thermal energy varies from 4.5 to 6.7%. It should be remembered that the temporary liner thicknesses assumed for this study are very conservative, and affect the power required and costs directly. Nevertheless, the cost contribution of thermal energy is certainly not dominant.

Power costs can be expressed in another manner, i.e., in terms of costs per kWh. Fig. 14 compares purchased electric power costs from two sources with those used in this study. The NSTM data shown are for Type-I NSTMs and for 4- and 12-m-diam tunnels. The bar at the left of the figure represents rates in dollars/kWh(e) as quoted for Los Alamos, NM,[25] whereas the bar in the middle is a national average rate estimated by Hanold.[7] These two rates are 0.014 and 0.020 $/kWh(e), respectively. These data are based on power delivered to existing transmission terminals near the tunnel portal and do not take into account special hookup costs. Also, 100% conversion efficiency from electricity to heat is assumed. A factor to be considered is the regional aspect of electric power costs, which can vary significantly depending on location. For nuclear-supplied thermal power (delivered directly to the working face), costs range from 0.006 to 0.011 $/kWh (thermal) depending on tunnel size.

D. NSTM Development Benefit-to-Cost Ratios

No detailed estimates of overall future excavation demands for the world or the U.S. were

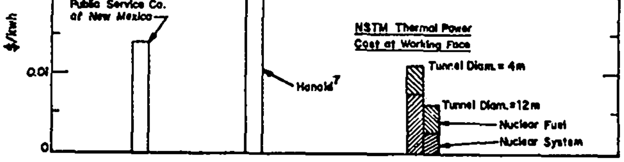


Fig. 14. Typical electric and NSTM thermal power costs.

TABLE VIII

PROJECTED U.S. TUNNELING EXPENDITURES

Time Period	Average Expenditures, B $* Transportation Only	All Tunneling Except Mining
1970-1979	5.1	34
1980-1989	9.3	65

* Based on 1969 dollars.

readily available. However, large future demands are anticipated in such activities as geothermal energy, mining, scientific studies, waste disposal, water redistribution, utility conduits, high-speed transportation, and urban facilities like airports, power plants, manufacturing plants, gas storage, housing, etc. Some recent projections for U.S. tunneling demands compiled by the U.S. Department of Transportation (D.O.T.) were obtained from Foster.[19] These projections can be used to show benefit-to-cost ratios based on NSTM savings indicated previously. They are shown in Table VIII. Ref. 19 also indicated that the percentages of the total excavation demands for rock and soft-ground tunnels are close to 50 and 20%, respectively, with the remaining 30% of the total consisting of cut-and-cover and immersed-tube demands.

Estimated Subterrene characteristics and program costs are summarized as follows: The program will lead to a feasibility demonstration of a prototype NSTM, at which time the technology will be available to industry. The program will cost about 100 million in 1969 dollars and will cover an eight-year period. After demonstration the industrial implementation of NSTMs will take place in a linear manner over a four-year period. The above process is illustrated in Fig. 15. The dotted lines indicate the early technology transfer from laboratory to industry. This is an important concept of the program proposed by LASL, wherein it is planned to: (1) cooperate with industrial firms interested in furthering the R&D effort of the Subterrene concept, (2) train key industrial technical personnel by encouraging them to work directly on the LASL team, and (3) award LASL subcontracts to industry to accomplish key elements of prototype fabrication.

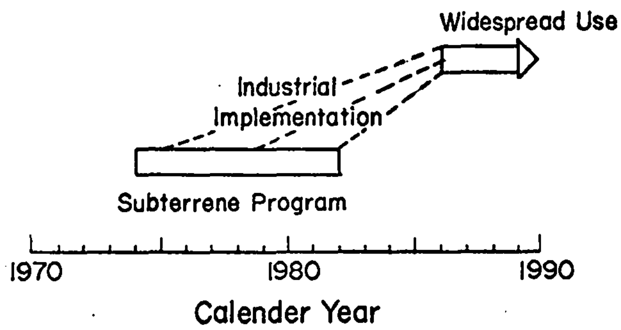


Fig. 15. Schedule for NSTM prototype demonstration and concept implementation.

In Section III-B, wherein NSTM vs TBM and conventional costs were discussed, an example of typical hard-rock costs showed NSTM cost savings of 34 and 46% over TBMs. Also, drill and blast methods are very undesirable in most urban environments and probably will be eliminated in many future projects. For soft ground, Fig. 13 showed that NSTM costs might very easily be less than half those of other methods. On the basis of these considerations the conclusion was reached that projects, excluding those where rock and soil conditions are very favorable for TBM or conventional methods, could be done at cost savings of 30 and 50% for rock and soft ground, respectively, if NSTMs are used.

Two more estimates are needed to arrive at a final benefit-to-cost ratio; both relate to the percentage of tunneling where NSTM systems show cost savings. These are estimated to be 50 and 75% for hard-rock and soft-ground tunnels, respectively. All cost assumptions are summarized in Table IX.

TABLE IX

NSTM COST ASSUMPTIONS AND BENEFITS TO CY 1990 BASED ON TRANSPORTATION DEMANDS ONLY

Type Tunnel	Fraction of Total, %	Demands Available to NSTM 1982 to 1990, B$	Fraction Assumed Done by NSTM, %	Average Savings, %	Benefit, B$
Rock	50	2.79	50	30	0.42
Soft Ground	20	1.17	75	50	0.43
				Total:	0.85

Net transportation benefit-to-cost ratio $= \frac{0.85}{0.10} = 8.5.$

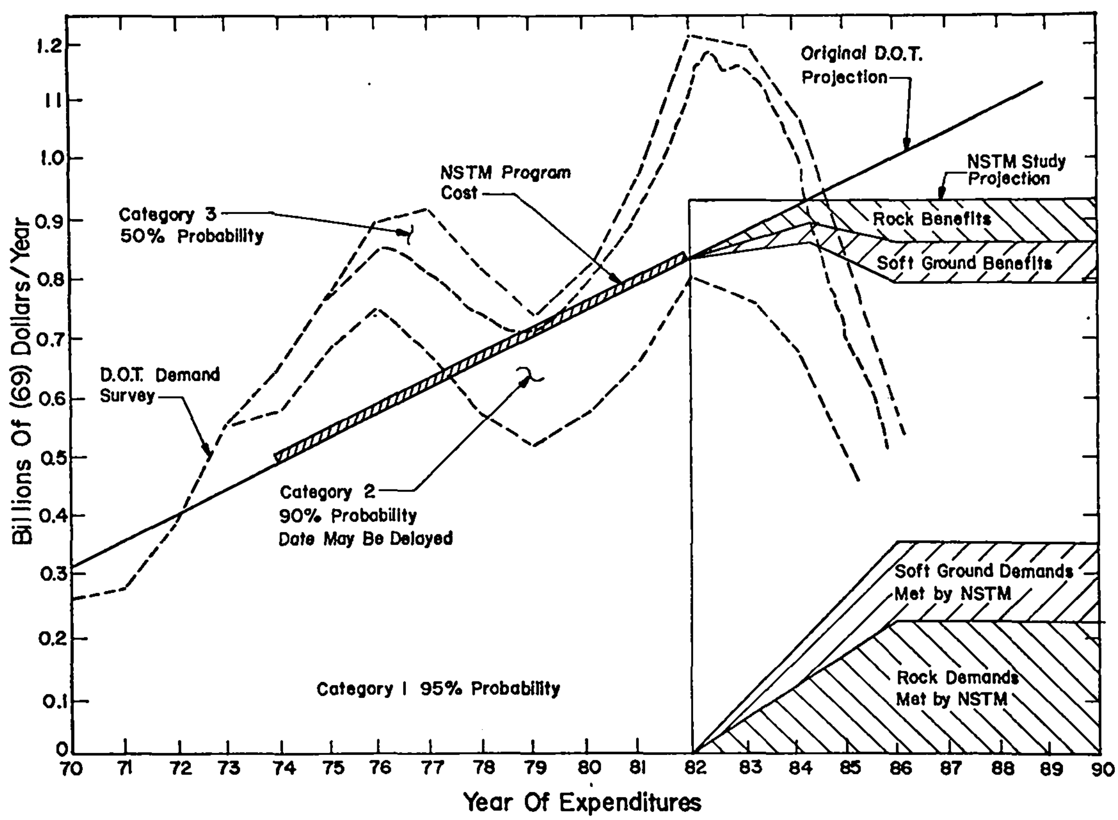


Fig. 16. Department of Transportation demand data and NSTM benefits.

The net benefit-to-cost ratio is 8.5 when based only on average projected transportation-tunnel excavation demands up to CY 1990. Fig. 16 plots the original D.O.T.-projected transportation-tunneling demand* in billions of dollars per year (1969 dollars) to CY-1990 and some results of a later D.O.T. survey of demand which are categorized into 50, 90, and 95% probabilities of actual implementation. The demand curves show a rapid decrease after 1983, which (according to D.O.T.) is due to lack of planning beyond a ten-year lead time by government organizations and not to any expected actual decrease in need for transportation excavation projects.** The various shaded areas in Fig. 16 show the $100 million cost for prototype demonstration, the demands which were assumed as being met by NSTMs for both rock and soft-ground projects and, at the upper right, the benefits that would accrue from savings by use of NSTMs. Benefit-to-cost ratio is, of course, the integrated benefit area divided by the program cost area. These curves also emphasize that additional benefits will accrue if the project had been initiated earlier and shortened in duration.

E. Effect of Advance Rate on Tunneling Costs

The effect of changes in advance rate from the baseline rate of 36.5 m/d was studied. It was assumed that capital costs and design remained the same as those of the baseline configuration but that the system efficiency either increased or decreased to produce the change in penetration rates. The results are summarized in Fig. 17 where the ratio of tunnel cost at other rates to baseline tunnel project cost is plotted against advance rate. The point where the benefit-to-cost ratio would equal zero is at a cost ratio of 1.375, at an advance rate of 22 m/d (3 ft/h), which is well below the baseline rate of 36.5 m/d (5 ft/h). During penetration tests

*The average demands listed in Table VIII correspond to the data in Fig. 16 designated "Original D.O.T. Projection."

**A detailed study of past U.S. tunnel project history and development of more accurate and comprehensive methods of surveying future demands may reveal a basic cyclic trend.

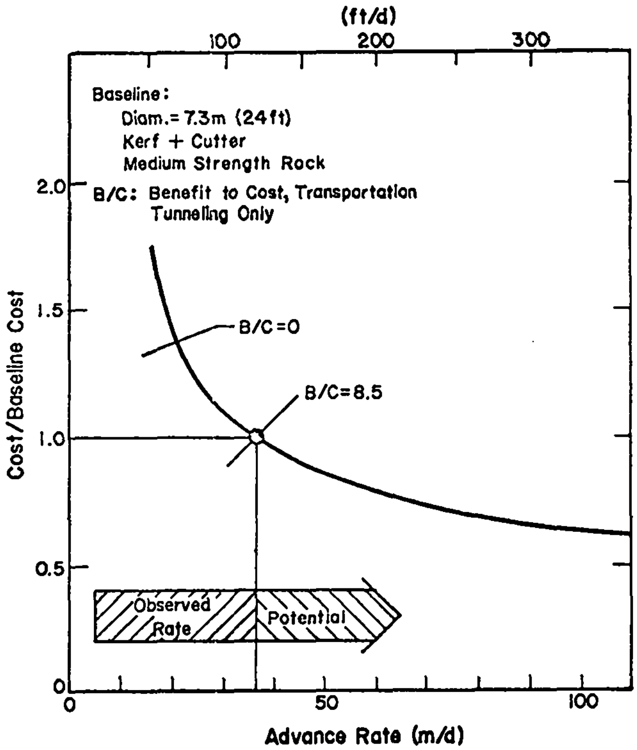


Fig. 17. Effect of advance rate on costs.

of small consolidating penetrators at LASL, rates of 24 m/d were generally recorded and, for short times, were as high as 36.5 m/d; however, at that time, no attempt was made to sustain such rates. Los Alamos Scientific Laboratory experimental experience suggests that a rate of 36.5 m/d is readily achievable and that higher rates are possible, as indicated in Fig. 17.

If the advance rate were twice the baseline value, i.e., about 80 m/d (~ 260 ft/day), an additional 30% savings may result. However, at some as yet undetermined high advance rate the cost may reach a minimum and then increase with further increases in advance rate. This may well be caused by a tradeoff with increasing costs of equipment, e.g., slurry pumps, piping, and crushers, increased cutter wear, longer glass-liner cooling sections, a larger nuclear power system, and larger portal power and coolant equipment. When this occurs a new system concept will become necessary. Such a new system might take advantage of full face melting as indicated by projected long life of melting penetrators (4500 h appears possible). Also, methods of lowering

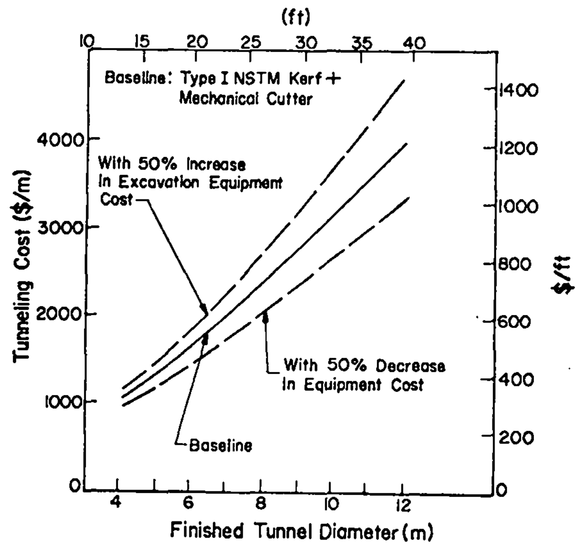


Fig. 18. Effect of ± 50% variation in NSTM excavation equipment costs.

the rock-melting temperature and reducing the viscosity of the melt should be given consideration.

F. Effect of ± 50% Excavation Equipment Cost Perturbation

A perturbation of ± 50% on excavation equipment costs around the baseline case was studied; results are shown in Fig. 18. The overall effects on tunnel project cost were ± 9 and ± 17% for tunnel diameters of 4.1 and 10.7 m, respectively. The upper-limit cost variations, if they occurred, would reduce the benefit-to-cost ratios to between 5 and 6 based on transportation-tunneling demands to 1990. Thus, we may conclude that results would not be affected significantly, even if equipment costs used in this study were greatly in error, e.g., by 50%.

G. Other Benefits Not Quantified In This Study

The benefit-to-cost ratio discussed to this point included only the excavation demands for transportation, i.e., average of 9.3 billion dollars for the period 1980-1989. As was shown in Table VIII, an additional 56 billion dollars of excavation demand is foreseen during that time period for other tunneling projects, excluding mining. Thus, with the inclusion of these additional demands, the benefit-to-cost ratio could become considerably larger.

Conceivably, as experience is gained with the glass liner, the concrete structural wall inside the glass liner could be eliminated or greatly

minimized. This would result in further savings in support costs. Another NSTM advantage that should be kept in mind is offered by the fact that the NSTM can advance through the earth with a minimum of disturbance, thus maintaining the inherent strength of the surrounding strata and, in fact, enhancing their integrity by the cementing action of the solidifying glass. Emphasizing this point Cording and Deere,[27] discussing tunnel support loadings, point out that liner loadings can be rather low even in highly fractured rock, if the joints are tight and irregular and if initial loosening is prevented.

Technology spin-off benefits from NSTM development could include high-temperature abrasion-resistant materials and high-temperature, high-heat-flux, long heat pipes; such heat pipes could be useful in high-temperature chemical processes, e.g., coal gasification. Another spin-off or parallel development could be that of small electrically powered penetrators for installation of underground utility lines, for exploration of natural resources, or for mining. One of the most important Subterrene applications could be the deep penetration into the earth's crust to tap geothermal energy[26] for such purposes as water desalination, surface heating, and electric power generation.

IV. CONCLUSIONS

The designs and characteristics of two large Nuclear Subterrene Tunneling Machines (NSTMs) were postulated and their cost-effectiveness for future transportation tunnel projects was analyzed. Both designs are first-order extensions of present Tunnel Boring Machine (TBM) technology and visualize the addition of a peripheral kerf-melting penetrator, which will form a continuous temporary support by lining the tunnel walls with rock glass. High cost-effectiveness is projected for both soft-ground and very-hard-rock tunneling. Contributing to this projection is the anticipation that NSTMs will be relatively insensitive to variable and unexpected formation changes.

The major results of the study are:

- The preliminary economic analysis indicates excellent cost benefits for the development of NSTM systems. Estimating that unfavorable excavation conditions would be encountered at least 50% of the time in rock and 75% of the time in soft ground, and using the best available estimates for hard-rock and soft-ground excavation demands in only the transportation sector up to CY 1990, the benefit-to-cost ratio for a Subterrene development program is 8.5. Many other potential benefits outside of transportation applications could increase this ratio significantly.
- Additional benefits will accrue if research and industrial implementation are accelerated. LASL program plans are based on early transfer and availability of the technology to industry.
- As an initial step, large NSTMs using the peripheral kerf-melting bit concept can be integrated into technically sound excavation systems.
- For a conservative temporary glass-liner wall thickness equal to 4% of tunnel diameter, the nuclear thermal power requirements are 7 and 63 MW for 4- and 12-m-diam tunnels, respectively.
- The cost of the thermal power required to melt the rock is only about 4 to 7% of the total excavation project cost.
- NSTMs are capital-intensive systems as compared to the labor-intensive TBMs.
- Penetrator material costs appear to be the highest cost item, on a cost-per-unit tunnel length basis, followed by the cost for mechanical rotary cutters used to fragment the central areas of the excavation face.
- The total costs for excavation, materials handling, and supports and liners, using NSTMs, are very close to those for TBMs when ground conditions are favorable. However, the advantages of NSTMs become outstanding in unfavorable ground conditions such as in very hard rock and, particularly, in soft, wet, running, or bouldery ground.
- Very high advance rates may require design extensions beyond the two NSTM concepts analyzed in this study.

Additional investigations in the following areas are needed:

- Continue more detailed preliminary design studies of NSTM tunneling system.

- Develop more specific future tunneling demand data (both in the U.S. and overseas); including sizes, geological conditions and variations, project locations, applications, and schedules.
- Study other NSTM designs which will encompass full-face melting designs and include removal of molten rock from the tunnel.
- Develop system concepts and costs for Electric Subterrene Tunneling Machines (ESTMs) and compare with NSTMs and TBMs.
- Evaluate the details of the supply and cost problems of exotic components such as refractory penetrator bits.
- Determine the most likely benefits achievable by actively pursuing R&D related to TBM and conventional methods, and compare with ESTM and NSTM benefits.
- Study the environmental and social impact of ESTM and NSTM full-scale implementation.
- Adapt COHART or the General Research Corp. computer program to obtain additional useful cost study data.
- Conduct investigations and tests to verify glass wall properties and their wall-support characteristics.
- Study effects on the overall system design of greatly increasing the advance rate.
- Initiate failure-mode analyses, conduct maintainability studies, and develop component life data.

REFERENCES

1. R. F. Baker et al, "The Use of Underground Space to Achieve National Goals," The Underground Construction Research Council - American Society of Civil Engineers, Final Report to the National Science Foundation (June 30, 1972).
2. Eugene P. Pfleider, Chairman, "Rapid Excavation-Significance-Needs-Opportunities," National Research Council, National Academy of Sciences, Washington, DC (1968).
3. M. C. Smith, Editor, "A Preliminary Study of the Nuclear Subterrene," Los Alamos Scientific Laboratory Report LA-4547 (April 1971).
4. D. L. Sims, "Identification of Potential Applications for Rock-Melting Subterrenes," Los Alamos Scientific Laboratory Report LA-5206-MS (February 1973).
5. R. G. Gido, "Subterrene Penetration Rate: Melting Power Relationship," Los Alamos Scientific Laboratory Report LA-5204-MS (February 1973).
6. R. G. Gido, "Description of Field Test for Rock-Melting Penetration," Los Alamos Scientific Laboratory Report LA-5213-MS (February 1973).
7. R. J. Hanold, "Subterrene Rock-Melting Tunnel-Excavation Systems. A Preliminary Study," Los Alamos Scientific Laboratory Report LA-5210-MS (February 1973).
8. R. R. Hibbard and L. M. Pietrzak, "Computer Simulation of Hard Rock Tunneling," General Research Corp., Arlington, VA. Final Technical Report CR-2-190, Vol. I, (July 1972), Analysis, and Vol. II (November 1972), Supporting Information.
9. Tunneling Technology Newsletter, No. 2, National Academy of Sciences - National Academy of Engineering, U.S. National Committee on Tunneling Technology (June 1973).
10. H. W. Parker and R. M. Semple, "Development and Large-Scale Testing of Innovative Tunnel Support Systems," Proceedings, North American Rapid Excavation and Tunneling Conference, K. S. Lane and L. A. Garfield, Eds., Vol. I, pp 469-497 (Chicago, June 1972).
11. M. C. Krupka, "Phenomena Associated with the Process of Rock-Melting. Application to the Subterrene System," Los Alamos Scientific Laboratory Report LA-5208-MS (February 1973).
12. R. S. Mayo, "Tunneling - The State of the Art - A Review and Evaluation of Current Tunneling Techniques and Costs, with Emphasis on Their Application to Urban and Rapid Transit Systems in the U.S.A.," U.S. Department of Housing and Urban Development, NTIS No. PB 178036 (January 1965).
13. D. U. Deere, "Geologic Considerations," Rock Mechanics in Engineering Practice, K. G. Stagg and O. C. Zienkiewicz, Eds., (John Wiley and Sons Inc., New York, 1966) Chap. 1, pp. 1-20.
14. J. P. Carstens et al, "Heat Assisted Tunnel Boring Machines," United Aircraft Corporation, East Hartford, CT, Report FRA-RT-71-63, NTIS No. PB-197-243 (September 1970).
15. Norman N. Barish, "Capital Planning and Budgeting," Economic Analysis for Engineering and Managerial Decision-Making (McGraw-Hill Book Co., Inc., 1962) Chap. 16.
16. "Survey of Current Business," U.S. Department of Commerce; Vol. 51, No. 7, (July 1971) and Vol. 53, No. 2 (February 1973).
17. R. W. Kupp, Vice President, S. M. Stoller Corp., New York, NY, data released at Los Alamos Scientific Laboratory, June 5 and 6, 1973.
18. J. M. Duncan, M.P. Tierney, and H. V. Schneider, "Materials Handling for Tunneling," Holmes and Narver, Inc., Report No. FRA-RT-71-57 (September 1970).
19. E. L. Foster, Chief, Tunneling Projects Office, Department of Transportation, personal communication (April 1973).

20. F. T. Wheby and E. M. Cikanek, "A Computer Program for Estimating Costs of Hard Rock Tunneling (COHART)," Harza Engineering Co., Chicago, IL, NTIS No. PB-193-272 (1970).

21. L. A. Spittal et al, "Tunneling Cost Analysis" RMC Inc., Bethesda, MD, NTIS No. PB-201-363 (March 1971).

22. Advisory Conference on Tunneling, "Report on Soft Ground Tunneling," Washington, DC, Organization for Economic Cooperation and Development (OECD) (June 22-26, 1970).

23. Fenix and Scisson, Inc., and A. D. Little, Inc., "Systems Study of Soft Ground Tunneling," Washington, DC (May 1970).

24. H. Louthon and J. Minton, Virginia Department of Highways (October 1970).

25. Consumer rates published by the Public Service Company of New Mexico, effective April 24, 1972.

26. M. C. Smith, "Geothermal Energy," Los Alamos Scientific Laboratory Report LA-5289-MS. (May 1973).

27. E. J. Cording and D. U. Deere, "Rock Tunnel Supports and Field Measurements," Proceedings, North American Rapid Excavation and Tunneling Conference, K. S. Lane and L. A. Garfield, Eds., Vol. 1, Chap. 33 (Chicago, June 1972).

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

AD-A032 172

The Very High Speed Transit System

Rand Corp Santa Monica Calif

Aug 72

THE VERY HIGH SPEED TRANSIT SYSTEM

R. M. Salter

August 1972

P-4874

THE VERY HIGH SPEED TRANSIT SYSTEM

The Concept

The Very High Speed Transit or "VHST" concept was put forward some years ago in response to the search for a pollution-free transport method that could operate at speeds competitive with aircraft. The general principles are relatively straightforward: electromagnetically levitated and propelled cars in an evacuated tunnel.

The VHST is predicated as an addition to the future transportation scene and will offer not only a fast and convenient transit method but also a tunnel complex to house utility transmission and auxiliary freight-carrying systems.

It is assumed that future transportation approaches will be extensions of present ones, including subways for local mass transit and automobiles for the bulk of intracity and intercity travel. Autos have performed over 90 percent of the travel between cities over the last two decades; although it is not predicted that this will significantly decrease, it is expected that there will be improvements in automotive vehicles to make them safer and environmentally acceptable, that there will be improved mass transit (with added "people-mover" systems) to handle local traffic, and that much better interfaces will be established between these modes of travel. The VHST is designed to connect directly with local systems. It is visualized that a passenger steps off a subway (or a people-mover from an auto parking facility) and gets on a VHST vehicle in the same terminal.

The VHST's "tubecraft" ride on, and are driven by, electromagnetic (EM) waves much as a surfboard rides the ocean's waves. The EM waves are generated by pulsed or by oscillating currents in electrical conductors that form the "roadbed" structure in the evacuated "tubeway." Opposing magnetic fields in the vehicle are generated by means of a loop of superconducting cable carrying on the order of a million amperes of current.

The system is highly conservative of energy. The tubetrain is accelerated to its maximum velocity, coasts for a brief period, and

then is decelarated. Nearly all the power goes into kinetic energy; in accelerating, it employs the energy of the surrounding EM fields, but like trolley cars of the past, in decelerating, it returns this energy to the system. Its optimized electrical drive system is quite efficient, and further, it does not have to squander unrecoverable energy in climbing to high altitudes, as does an aircraft.

What sort of speeds are needed and how might these be achieved? Speeds as high as 14,000 mph have been examined in studies by the Rand Corporation* (in an example case of a direct link between Los Angeles and New York requiring 21 minutes transit time). The speeds required will certainly be on the order of thousands of miles per hour on the long-haul links.

Because of the rather considerable expense of the tunnels, it is probable that the first VHST system will not rely on a direct nonstop LA-NY link, but rather one that stops at two intermediate staging points. If the route is in several segments, additional flexibility is gained in routing and some latitude is given in the schedule for acceleration. There will be intermediate links in the overall system of up to several hundred miles; in these, compatible speeds will be commensurately lower.

Figure 1 schematically illustrates an overall system. Vehicles from feeder links are phased into the ends and two interchange points of the main coast-to-coast channel. Likely intermediate terminals are Amarillo and Chicago. A search for an optimal routing would present an interesting and challenging problem, requiring an extensive data bank of physiographic information.

There also would be subsidiary lines coming into the two main terminals from such places as San Francisco, Boston, and Denver. The best routing for any particular trip would be shown on a computer display, continuously updated, which would indicate whether a through tubetrain or a combination of shorter hops would be the faster mode.

---

*It should be noted that certain features relating to vehicle control and damping, accommodation of earth tremors, hull construction, and passenger comfort are presently under patent investigation by the Rand Corporation and cannot be discussed here.

The VHST route system

Environmental Benefits

Transportation systems pose well known problems to the environment. The bitter controversy over the sonic booms of the SST has perhaps obscured some other environmental effects of the SST -- and aircraft in general. None of the energy required to levitate and propel the aircraft is recoverable; it all goes into the atmosphere along with combustion products. Long-term buildup of these products in the upper atmosphere is a matter of concern, and is a process that we are just beginning to understand. As aircraft become faster, airports must become more remote and operating altitudes higher, both aspects contributing further to environmental problems.

The use of a tubetrain would alleviate these hazards to the environment; aesthetic considerations, advantageous relocation of utilities, and protection against sabotage would also suggest the desirability of underground tunnels for these systems. Right-of-way costs, surface congestion, grade separation problems, and noise pollution would be eliminated.

Sharing of facilities could help pay the high cost of such tunnels. Included among these contemplated underground systems are pipelines for oil, water, gas, waste disposal, and slurries of materials such as coal and other bulk commodities; communication links, including channels for lasers and microwave waveguides; electrical power transmission lines such as superconducting cables; and passenger and freight-hauling systems.

Superconducting power cables will require a controlled environment to protect the cryogenic refrigeration system that makes superconduction feasible. A controlled-access tunnel is a virtual necessity for such a system. This type of power cable will alleviate many of the problems of siting of future power stations, since they can be located at great distances from the user and yet suffer negligible power losses in transmission. Nuclear reactors, for example, could be located in colder regions and the thermal effects of their cooling effluent employed in such useful ways as to enhance growth in fish "farms."

Laser communication channels along with "repeater" stations will most certainly require the protection of an enclosed channel. Since

the tunnels have limited diameter and follow the earth's curvature* while the laser propagates in a straight line, there will be a number of stations needed to refresh and redirect the laser beams. Many thousands of video channels are visualized for these future laser links.

Economic Aspects

Subways are an example of a short-haul transport system that can warrant the costs of underground facilities because of the high volume of traffic that they handle. In the medium-haul regime it would be difficult to build a case for going underground except as demanded by environmental considerations. The question is: Can underground transport be justified on a longer-haul basis? Tentative analyses show that underground long-haul domestic travel can pay for itself, even without mutual economic benefits from sharing the tunnel complex with other underground systems.

Such a system must operate at very high speeds in order to compete with the alternative modes of travel (i.e., aircraft). It further must take advantage of its underground character that permits its integration with local transit systems (i.e., subways and people-movers). The convenience of such an integrated system will help build the passenger volume needed to put the overall system on a self-paying basis.

Economics of the system are based upon high volume induced through overall passenger convenience. Not only does the passenger travel in total indifference to rain, snow, wind, clouds, or heat (a state which no mode of travel on or above the surface can claim), but the time for travel from the heart of one city to the heart of another is radically reduced.

Rand's preliminary investigations have included the above-mentioned cross-country time of 21 minutes, which was a constant one-g acceleration/deceleration, nonstop case. With this same acceleration and with two intermediate stops, the coast-to-coast time would be increased from 21 to 37 minutes. For a passenger traveling from San Francisco to Boston,

---

*A tunnel following a chord of the earth's circumference between Los Angeles and New York would be some 200 miles beneath the surface at its midpoint.

the overall time is 51 minutes on a minimum-schedule basis.*

If we postulate 100-passenger cars operating on one minute headways in the central corridor, this amounts to almost 290,000 passenger (or freight equivalent) movements across the country per day. This is on the order of 106 million passenger trips per year. If we take the present total domestic air traffic of 150 million and reduce it to account for the longer-haul portions only, but also increase it for future traffic growth, we arrive at a figure similar to that assumed for the VHST. Another way of looking at it is that this rate is equivalent to cross-country air traffic (including that stopping at major intermediate terminals such as Chicago) of a dozen or so jumbo jets per hour. However, if the VHST offers greatly reduced travel time at a reasonably low fare (say $50 each way), this would undoubtedly cause new travel patterns to develop and perhaps even create a much larger demand than the 106 million/year level. Thus the volume assumed here may be conservative in view of the convenience offered, and since operating costs are only a few percent of the fare, the fare can be nearly halved when the volume is doubled.

Assuming the 106 million/year volume at $50 coast-to-coast fare gives roughly $5.3 billion per year gross revenue, of which (as we will see later) operating costs are an insignificant fraction. On a 30-year payout basis, this means we can afford a $90 billion cost for the central corridor part of the system. This works out to be about $30 million/mile of double tube system.

Since the amortized cost of the facility is the overriding factor, we might consider adding additional VHST cars solely for freight purposes. With a 12-fold increase in volume (five-second headways), freight costs would be around 1¢ per ton-mile. Many freight items, including automobiles, could be carried this way. On this expanded-volume basis a traveler could take his car with him for a fare about the same as that for a passenger alone in the previous case.

---

*He would have a number of options, and computer displays would present the alternatives, e.g., wait for the next scheduled San Francisco-to-Boston car, take a scheduled New York car and disembark for the next New York-Boston run, or change in both Los Angeles and New York. There are, of course, other possibilities involving changing cars at the Texas and Chicago interchanges, given the system shown in Fig. 1.

A complementary steel-wheels-on-rail, 100-mph, heavy freight system that readily interfaces with railroad systems and collocates with the VHST tunnel complex is described later. This latter could move 7 million tons of freight across the country daily. Joint use of the tunnel complex, as previously discussed, will reduce the effective cost for any one user.

Technical Aspects

The most demanding technical problem is that of lateral accelerations. A vehicle traveling at 550 mph cannot undergo sharp turns. In order to keep the magnitude of these sideways forces down to one g (i.e., equal to the vehicle's weight) the radius of bend of the track cannot be smaller than 4 miles. At 5500 mph this radius must be greater than 400 miles. This requirement imposes strong constraints on the design of the guideway and would create a great difficulty if one attempted to run the VHST tubes above ground.

On the other hand, locating the system underground can overcome this difficulty and has a number of contingent benefits, particularly those of environmental improvement discussed above. Furthermore, even at the present time, when considering grade crossings, right-of-way costs, etc., the cost of a tunnel is not significantly greater than that of a surface system -- and this doesn't take into account potential decreases in tunneling costs through use of new technology.

Once the assumption is made that underground tunnels are necessary in order to travel at speeds competitive with present (and future) aircraft, another aspect of the problem becomes evident. Over 90 percent of the system cost will result from the tunnel itself. This situation applies even if very expensive guideway and vehicle hardware is employed. This then suggests that we can afford to incorporate very sophisticated transport systems into the tunnel if these systems contribute to increased utilization of the tunnels in even a small way. The fact that these sophisticated approaches offer a much greater increase in system capacity sets the optimum cost tradeoff at the high-speed end of the spectrum.

In order to attain these high speeds we cannot follow conventional avenues. Even the presently DoT-supported magnetic levitation (MagLev) schemes (which utilize passive guideways) are inadequate. What is needed instead is a fully active guideway system that is highly precise. Every point in the vehicle's trajectory has an exact design condition that must be met -- only minor excursions are permitted, and these are continuously corrected for. Thus, for example, at mile 427 the design requirement might be for a speed of 723 mph at a thrust angle of 47.8° and a thrust force of 1.38 g. Every car as it passes this point must meet this precise requirement.

Careful matching of the thrust vector at every point along the way will yield high efficiency. Use of a superconducting current loop in the vehicle to oppose the driving fields of the roadbed stator conductors will provide for a substantial clearance (of the order of a foot), which is needed in vehicle control at high speeds. The optimized matching process will reduce make-up power into the vehicle's conductors to a very small amount. Cryogenic fluids (to keep the vehicle's conductors at superconducting temperatures) will not be actively refrigerated underway but will be replaced at terminal points. Boil-off will be stored enroute and recycled at terminals during "turnaround" of cars.

The conductors in the guideway are heavy bus bars, and currents are properly phased to levitate, propel, and control the vehicle. Different EM wave forms and propagation methods have been considered. The most effective mechanism is a traveling wave, but it requires triggering circuits and pulse-forming networks. The standing-wave approach requires less electronic hardware but takes about twice as much current (on the average) in the stator conductors. A detailed tradeoff analysis of these choices has not yet been made.

Another tradeoff exists in the amount of atmosphere in the tunnel. High vacuum would require expensive diffusion or ion pumps and much power. On the other hand, too much air will create drag and heating problems. A good compromise is to use vacuum "roughing" pumps only, to pump down to a pressure of about 0.5 mmHg (equivalent to 170,000 ft altitude).

At these pressures the air molecules essentially travel on independent paths (Newtonian flow condition) and the vehicle drag is a function of the presented area only. Streamlining is thus not required. Heating takes place only at the nose and this is negligible. However, there will be a heat shield incorporated to protect against heating caused by air in the tunnel should a major leak occur. If the final design requires that the cars be cooled, a self-contained heat reservoir can be used that is recharged during turnaround.

Assuming a pumpdown to a vacuum of 0.5 mmHg in approximately nine hours, the 5,000 miles of vacuum shell would require only $78 million in pumps (two 2600 cfm roughing pumps per mile). Furthermore, there would be considerable over-capacity for handling leakage. (Normal leak rate is estimated at 77 liters/sec/mile.) The power to maintain the vacuum is not negligible and is of the order of the operating power for the cars. (Total power cost, on the other hand, is small compared to fare revenues or amortized system investment costs.)

At terminal points there must be a quick-opening gate (or gates) and differential pumping to maintain the tube vacuum. Guillotine-type doors can be considered and can be automatically timed for the passage of the vehicle. The door would be somewhat larger than the enclosure so that it could be set in motion before actual opening or closing. Some sort of a compliant, labyrinth structure can be used to minimize clearance between vehicle and enclosure at the vacuum locks. The vehicle's speed in this regime is low and optimized to produce the most satisfactory solution to the vacuum-lock problem.

Tunneling Considerations

As mentioned above, the lateral-acceleration problem is one of the most difficult of the VHST problems. Assumption of the use of tunneling will greatly alleviate the problem of proper selection of a routeway to minimize lateral accelerations -- particularly in the very high speed regimes. Even if tunneling does not provide the minimum cost solution, it probably will permit minimizing transit times and environmental disturbance. Thus both for passenger convenience

and for environmental quality, there would be strong justifications for an all-underground VHST system. To this rationale can be added the joint benefits from an underground utility network, other transportation systems sharing the complex, and the potential for defense purposes.

At the first International Advisory Conference on Tunneling, sponsored by the Organization for Economic Cooperation and Development (OECD), designed to stimulate more rapid progress in tunneling technology, it was brought out that the technology of tunneling offers great potential for alleviating a wide range of problems related to urbanization.* At least 8000 miles of tunnels were constructed in the 1960s, and a survey report showed that demand for tunnel construction in the 1970s will be at least double this figure.

It is difficult to estimate tunneling costs accurately because the technology is rapidly changing. A recent study for the Office of High Speed Ground Transportation (OHSGT) of DoT suggested that the various future needs for tunnels will create a demand that will cause a reduction of 30 to 50 percent in tunneling costs and an increase in tunneling advance rates of 200 to 300 percent. These improvements can be achieved only by consistent development in all facets of tunnel construction. New techniques under development involve a systematic and more automated matching of excavation techniques, tunnel support installations, transport of excavated material out of -- and construction materials and personnel into -- the tunnel, liner construction, and environmental-control concepts.

Inherent limitations of the cyclic or conventional method of tunneling suggest that the new approaches must include continuous or semi-continuous excavating machines. Augmented rotary drills, e.g., turbine drills and vibrating-bit drills, have shown some promise. These have demonstrated sustained advance rates of 200 ft per day with short-duration rates of 400 ft per day. They are also capable of drilling holes of perhaps 10 m diameter. Their drawbacks include the

---

*<u>Engineering News Record</u>, July 2, 1970.

difficulty with which bits are replaced and the frequency of such replacement, resulting in more than 50 percent down time. They also experience difficulties in very hard rock formations, e.g., igneous rock.

High-pressure water jets have been tried as so-called erosion drills. With these, power requirements are high, and present designs experience severe nozzle erosion; the necessity for wall and roof support provides another major problem. Other erosion drills employ abrasive jets using sand or other abrasive materials, even steel pellets; these have been found inefficient and of low speed.

The use of explosives in shaped-charge blasting shows good promise, although the advance rate is slow, and personnel and equipment operating close to the working face must be protected. Explosive drills, which employ small charges set off near their tips, have proved high in cost, although they show good penetration except in soft or plastic rocks.

The "jet-piercing" or flame-jet drill is an example of a proposed spallation drill. Lasers, electron beams, and acoustic transducers have also been investigated. These spallation methods too encounter difficulties with igneous formations. Laser photons and electrons can be made energetic enough to melt their way through rock, but the process is highly energy intensive. The "compacting auger," which is essentially a wedge continuously driven forward, needs excessive force to operate and is limited to highly porous or unconsolidated material. Chemical softening of rocks might prove useful to condition the material for conventional drills; however, handling difficulties preclude using chemicals for complete removal of rock.

All of the above methods of drilling present the problem of debris removal, especially the faster ones where the removal system is constantly lengthening at a high rate of speed. Two systems have been proposed that hold some promise, according to the aforementioned OHSGT study:

1. The side-wheel powered drive concept which consists of trains of cars running on rails, propelled by stationary motors driving pneumatic-tired wheels acting against the sides of the cars.

2. The hydraulic muck transport system for both horizontal and vertical transport of muck, operating in conjunction with

either rail or truck haulage for the transport of incoming construction materials.

Perhaps the most promising drilling technique of all, however, and one which provides its own debris-removal system, is the rock-melting drill currently under investigation at the Los Alamos Scientific Laboratory (LASL). In preliminary tests, rock-melting has proved to have a very high advance rate, is efficient in most kinds of rock (especially igneous), does not rotate so that the hole can be created in any shape, would not endanger personnel, and creates its own lining of strong, glass-like material. This latter ensures that there need be no constant shoring-up of walls and ceilings of tunnels, as well as provides a pressure-tight, impervious lining.

The energy source for the rock-melting drill (dubbed "Subterrene" by LASL) is electrical or nuclear. The latter version is compact and self-contained and would be used in large tunneling operations. It requires 50 MW power, based on 25 percent melting (only an annular region of rock is melted, the rest removed as core). The drill itself is tungsten or a niobium-zirconium alloy. The advance rate is predicted at 100 m/day or 12 ft/hr, significantly faster than any other proposed drilling method. Further research has been proposed on a laser system for guidance or development of subterranean telemetry or self-contained pre-programmed guidance systems.

The debris-removal problem is eased by the formation of the glass lining from some of the rock. Molten rock is forced into cracks in the surrounding formation as well, adding strength and eliminating still more debris. The remainder of the excavated material is either removed as scoriae via a helical debris conveyor contained in the drill apparatus itself or may be extruded as a glass-covered core (which, cut into usable sections on the spot, might be easily transported to construction sites on the surface).

It is evident that with the above-mentioned advances in drilling and tunneling technology, the most appropriate and efficient method could be found for advancing through each type of rock or soil found along the VHST routeway. Cost tradeoffs would have to be studied in the light of geologic information on each region. Tunneling could

begin in one area with one type of drill concurrently with other areas and other types of drills.

Exploration and mapping of geologic formations on a vastly expanded scale over existing data will be necessary for the VHST. Use of smaller versions of the Subterrene to drill test holes will facilitate a program of this magnitude.

Each of the above modes of drilling (except most of the Subterrene cases) requires that a tunnel lining be used. Prestressed high-strength concrete is a candidate both for the tube's vacuum shell and for tunnel lining. In previous Rand studies of linings of tunnels for defense purposes, the prospects were discussed for using 10,000 psi concrete, with distributed polymers and irradiated for bond strengthening. Rand has also recently investigated very high flux particle accelerators, which could be applied to make manufacture of such high-strength concrete an economical process.

However, even present-day prestressed concrete might be suitable. Nine-foot concrete pipe conduits for the Feather River Water Project were contracted for at $182/ft, which would equal less than $5 billion for 5,000 miles of vacuum shell. Such concrete may be dense enough for vacuum purposes, but if not, wall coating with plastic or glaze could be considered. Joints are probably simple sleeve clamps over O-ring type packaging with some allowance for cocking of one tube section relative to the next for alignment changes. Constraint in the longitudinal direction is considered unnecessary.

It is noteworthy that tunneling at great depths is not much more difficult than tunneling at shallow depths.* In fact, it may be somewhat easier since the rock at greater depths may be more competent and consistent. This fact makes it conceptually possible to consider tunneling under deep water. A tunnel following the great circle route from Seattle to Paris would not require going under any ocean deeps, and in fact, would be under land masses most of the distance; the maximum depth requirement would be generally less than one mile.

---

*Rand studies of tunnels for hardening of defense installations indicate that except for the additional lift at tunnel ends for material removal, there should be little difference in tunneling at 5600 ft versus 200 ft depth.

A Companion Freight Transport System

The development of a routeway for a VHST system would offer the potential for the collocation of an advanced freight transport system (Fast Rail System or "FRS"). Such a system would be designed to interface with existing railroads and to carry semitrailers, container cargo, campers, and items too bulky to fit the configuration of the VHST cars. Its guideway would be collocated with VHST tunnels and share power and service installations.

The FRS could consist of a transcontinental link plus several cross links. Trains would probably travel at 100 mph, would be highly streamlined, electrically "driven," and would comprise a dozen or so cars, each of which would be large enough to hold a standard railroad car. (Cars could be of different sizes to accommodate various railroad car sizes or other cargo.)

At 100 mph, with a well streamlined train, the required power per car is about 100 hp, about equally divided between rolling and air friction. (Wheeled support is probably the best choice at this speed and for this purpose -- although a Tracked Air Cushion Vehicle (TACV) might be found more cost-effective in a tradeoff of power consumption versus investment.) Some additional power is needed for station-keeping and for climbing grades. To accelerate to 100 mph in a reasonable distance would require several hundred horsepower per car. Gravity might be used to bring cars up to speed from the marshalling yards and to decelerate them upon return to the yards; a drop of about 300 ft is needed for the acceleration considered. However, this added constraint on rail facilities may be more costly than the additional installed electrical power needed without gravity acceleration.

Loaded standard railway cars would be inserted into tube cars at marshalling yards. The tube cars in turn could be assembled to form a train of contiguous surface while being accelerated to tube speed or individually could be phased into a train in the tube. The cars would be interconnected to form trains of length sufficient to reduce air resistance. The trains can be reformed with only slight speed changes to isolate a slot to add or discharge a car from the system. Input/output maneuvers could be performed at any point where the roadway

altitude was compatible with surrounding territory, making FRS available to cities and areas where no VHST terminals exist.

Trains would be closely spaced and under phase-locked control. Coast-to-coast would take about a day in transit, which would obviate the need for transcontinental trucking and cut into many air-freight requirements. It would be a boon to container shipping, offering the long-sought "land bridge" coast-to-coast link.

Concluding Remarks

We have noted that the VHST system operates in its own rarified atmosphere at or below ground level, in contrast to high-speed aircraft, which must climb to altitude in order to operate in such an efficient regime. Most of the VHST cases considered at Rand took less time to go coast-to-coast than an aircraft would spend in climbing. Also the VHST's efficient use of electrical drive will permit recovery of most of the power expended in accelerating the vehicle, since during deceleration it is braked electrically, returning energy to the power lines. Thus the environment is benefitted both because the VHST is energy conservative and because it does not dump exhaust products and noise into the atmosphere.

Other environmental benefits seen are those accruing from collocation of utilities and a companion freight system in the VHST tunnel complex.

The technical problems associated with the VHST development are manifold and difficult -- but no scientific breakthroughs are required. Critical areas include tunnel alignment, vehicle lateral acceleration, vehicle control and damping, and the tunneling process itself.

The Ralph M. Parsons Company undertook a comprehensive analysis of the VHST, donating their efforts to Rand because of the future promise they believe the VHST offers. Their study assumed the use of the drill-and-blast method of tunneling as being best suited for the greater part of the route, and using shaped charges placed in pilot holes drilled by water jet. Further, Parsons analyzed the power requirements and did preliminary design of underground electrical sys-

tems, including dedicated power stations. (Interestingly enough, fossil fuel and nuclear reactor approaches showed comparable costs.)

Since the tunnel facility cost is an overwhelming portion of the total VHST system cost, there is need for it to pay for itself through high-traffic volume. Parsons showed that the electricity needed will cost less than $1 per passenger trip. On the basis of relatively low operating costs versus system fixed costs, it may be seen that the $50 fare per passenger trip based on 100 passengers leaving each coast per minute might be reduced to perhaps less than $10 if the traffic volume increases by a factor of 10. Of course we cannot accurately forecast the future demands on the system -- we can only speculate. Studies indicate, however, that with the availability, speed, and single-modal convenience offered by the VHST a high utilization rate is indicated. For example, a New Yorker could get off a subway, get on a VHST, and be in Los Angeles in less time than it now takes him to get to J. F. Kennedy airport. He could leave at lunch hour for a "morning" meeting on the west coast and be back home by quitting time. It is probable that some day we might even be able to link up American and EuroAfro-Asian systems by tunnels under the North Sea via Greenland and Iceland and via the Bering Strait.

Will such a system ever be developed? It should be said that the political outlook is much less optimistic than the technical one. For one thing there is no jurisprudence bearing on the freedom of underground movement akin to that for the skies and the high seas. History has shown that some obvious projects, such as tunneling under the English Channel proposed in the time of Napoleon, can be delayed for centuries because of political pressures. On the other hand, relatively primitive societies were able to achieve such engineering feats as the pyramids with a much larger proportional bite out of their gross national product than is posed by the VHST on our present GNP of $1.1 trillion. One interesting aspect that may be politically appealing is that the VHST tunneling job can be done many places simultaneously, utilizing local community resources.

Are there compelling reasons for the VHST? The answer to this is an emphatic yes!! We no longer can afford to continue to pollute our

skies with heat, chemicals, and noise, nor to carve up our wilderness areas and arable land for new surface routes. Nor can we continue our extravagant waste of limited fossil fuels. We need to get the bulk of truck traffic off highways and free these routes of much of the commuter auto traffic in order to restore to motorists the pleasure and convenience of driving through the countryside.

Is the VHST system really far-fetched? In order to gain proper perspective, it is instructive to look back over the last 100 years in transportation and see how far we've come.

However, in those 100 years, modes of transportation have proliferated with little or no attempt to integrate one with another. The efforts to move efficiently, safely, and sanely (environmentally speaking) both people and goods throughout the United States should be coordinated and plans made for this coordination as soon as possible. The VHST is specifically designed to be integrated with other existing and proposed transportation systems. Local rapid transit districts, utility companies, and transport authorities should be planning now to implement such an integrated system; the VHST would be a fitting starting point for such plans. The VHST concept has been advanced, the technology is presently available; needed now is the considerable research effort leading to the formulation of final, concise plans for its accomplishment.

6 8
28/73
LA-5422-MS

INFORMAL REPORT

Ah. 442

A Versatile Rock-Melting System for the Formation of Small-Diameter Horizontal Glass-Lined Holes

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

MASTER

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

In the interest of prompt distribution, this LAMS report was not edited by the Technical Information staff.

Printed in the United States of America. Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $4.00; Microfiche $0.95

LA-5422-MS
Informal Report
UC-38
ISSUED: October 1973

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

A Versatile Rock-Melting System for the Formation of Small-Diameter Horizontal Glass-Lined Holes

by

D. L. Sims

Work supported in part by a grant from the National Science Foundation, Research Applied to National Needs (RANN).

CONTENTS

I.	Introduction	1
	A. Program History	1
	B. Small-Diameter Horizontal Subterrene System	4
II.	System Description	5
III.	Summary of System Specifications	9
IV.	Description of LASL-Developed and Commercially Available Subcomponents	9
	A. General	9
	B. Description of Components	9
V.	Development Program	12
	A. Versatility of Hole-Forming Assembly	12
	B. Development of Attitude-Control Sensors	13
	C. Examples of Deviation Sensors	13
	D. Alignment Control Section (ACS)	15
VI.	Operations	16
VII.	Conclusions and Discussion	17
	APPENDIX	
	Analysis of Proposed Alignment Control Scheme	20

A VERSATILE ROCK-MELTING SYSTEM FOR THE FORMATION OF SMALL-DIAMETER HORIZONTAL GLASS-LINED HOLES

by

D. L. Sims

ABSTRACT

Rock-melting penetrators with diameters ranging from 50 mm (2 in.) to 76 mm (3 in.) have reached a stage of development at the Los Alamos Scientific Laboratory (LASL) which suggests that these devices are ready for practical application. Prototype refractory metal penetrators have formed glass-cased vertical holes of 26 m (82 ft) in a single run, and horizontal holes with diameters up to 127 mm (5 in.) are expected in the near future. These small horizontal holes can be used for underground utility conduits; for high-explosive shot emplacement; and as drainage holes to stabilize road cuts or embankments.

Design concepts and preliminary specifications are described for a Subterrene system that forms small-diameter horizontal holes in rock by melting and simultaneously lines the hole with glassy rock melt. Most components of the system are commercially available. Deviation sensors and alignment-control units can be added to ensure that the holes are straight. The design and operation of this Subterrene system are described and proposed development approaches for the hole-forming assembly are discussed.

I. INTRODUCTION

A. Program History

Rock-melting penetrators (Subterrenes) are under development at the Los Alamos Scientific Laboratory (LASL) to produce self-supporting glass-lined holes in rock and soil (Fig. 1) by progressive melting rather than by chipping, abrading, or spalling.[1] Rocks and soils melt at temperatures that are relatively high: common igneous rocks at ~ 1500 K, almost at the melting temperature of steel (1500 to 1800 K). Thus, the melting penetrators must utilize refractory metals such as molybdenum (Mo) and tungsten (W), which melt at 2880 and 3650 K, respectively, and which, in addition, have low creep rates at the rock-melting temperatures.

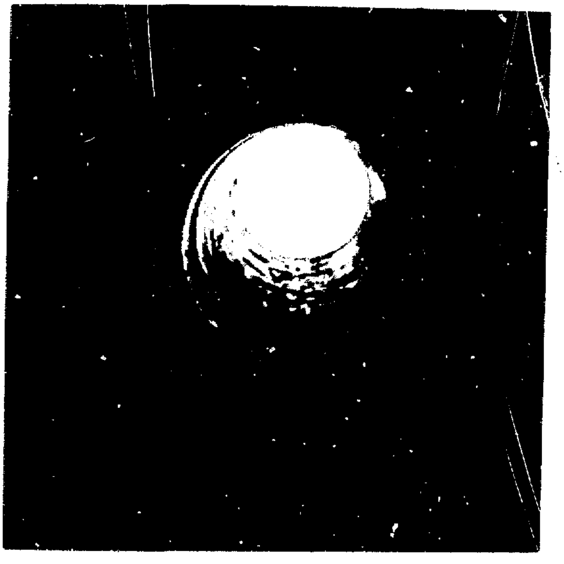


Fig. 1. Glass-lined hole melted in laboratory specimen of tuff.

Excavation by rock- and soil-melting offers potentially new and novel solutions to the three major areas of the excavation process:

- Making the hole or breaking up the rock.
- Providing structural support for the bore hole.
- Removing or displacing the debris or cuttings.

The liquid form of the rock- and soil-melt produced by a heated penetrator introduces new solution concepts into the latter two areas:

- The liquid melt can be formed into a glass lining to seal or support the walls of the bore hole, and
- Any excess liquid melt can be chilled and formed into glass rods, glass pellets, or rock wool (Figs. 2 and 3); or used to form a glass-cased core that can be removed by present wire-line methods.

The liquid melt produced by soil- and rock-melting techniques offers the potential of a complete systems approach to the processes of hole making, tunneling, and excavation. The LASL development program in rock- and soil-melting techniques has already demonstrated in laboratory and field tests an attractive advancement in practical excavation technology for the production of short, horizontal, small-diameter holes. This experience has been partially developed through the extensive testing of melting-consolidating penetrators[2] (MCPs). The tests consisted of:

- Melting 50-mm (2-in.)-diam, glass-lined drain holes in Indian ruins[3] at Bandelier National Monument (Fig. 4).
- Melting a 50-mm (2-in.)-diam glass-lined vertical hole in Los Alamos volcanic tuff to a depth of 26 m (82 ft) in a single run.[4]
- Melting a 50-mm (2-in.)-diam glass-lined horizontal hole in Los Alamos volcanic tuff to a length of 16 m (50 ft) (Figs. 5 and 6).
- Melting a sequence of 76-mm (3-in.)-diam glass-lined holes in volcanic tuff in the laboratory (Fig. 7).

Fig. 2. Hole melted in granite specimen with an extruding penetrator. Note debris.

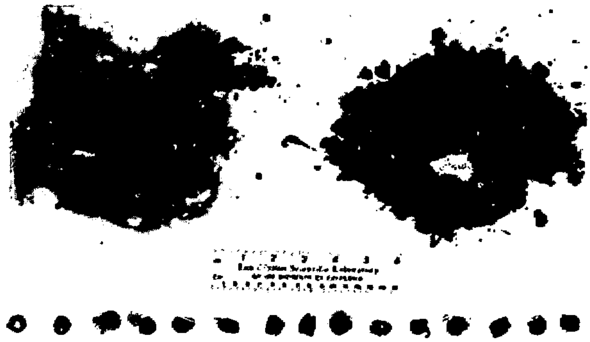


Fig. 3. Rock-wool and black glass debris from holes melted by extruding penetrator.

Fig. 4. Modular Subterrene field demonstration unit melting drain holes at Bandelier National Monument.

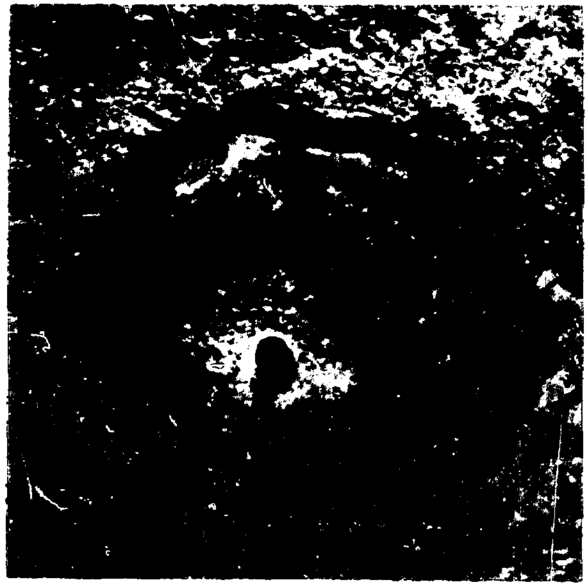


Fig. 5. Consolidating Subterrene Penetrator "holing through" a 16-m (50-ft)-long horizontal hole.

Fig. 6. Stem and service head in position to melt a 50-mm (2-in.)-diam horizontal hole.

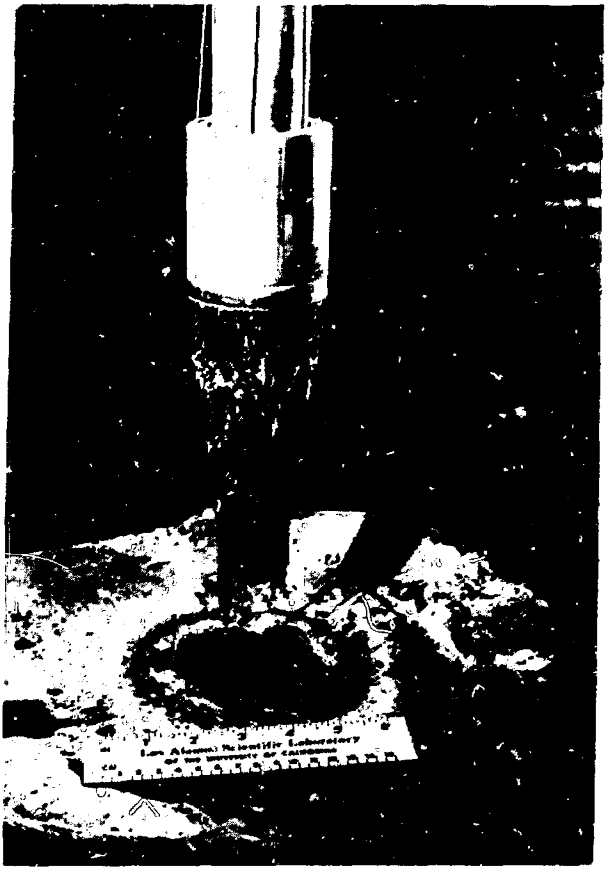


Fig. 7. Consolidating penetrator after melting a 76-mm (3-in.)-diam hole in Los Alamos tuff.

- Melting stable, 50-mm-diam glass-cased holes in shales, adobe, and alluvium (Fig. 8).

In addition, the prototype test program has developed a universal extruding penetrator (UEP) designed for hard, dense rock.[5] Tests with this unit have:

- Melted 66-mm (2.5-in.)-diam holes in basalt and granite (Fig. 2).
- Demonstrated the capability of tailoring debris for different applications to meet varying debris-return systems (Fig. 3).

A modularized, mobile field-test and demonstration unit[6] (Fig. 4) has been constructed, and was used successfully for melting glass-lined drainage holes in the floor of Indian ruins at Bandelier National Monument. This test rig will be used for additional field tests and for demonstrations of improved consolidating and extruding penetrators.

In addition, LASL is currently developing a 114-mm (4.5-in.)-diam, consolidating, coring penetrator that will produce a 63-mm (2.5-in.)-diam glass-encased core.

B. Small-Diameter Horizontal Subterrene System

The coring capability for the Subterrene, together with the commercial needs for horizontal holes for underground power lines[7,8] and a review of requests for information on the rock-melting Subterrene, has prompted the preparation of preliminary design concepts and specifications for a horizontal Subterrene capable of melting glass-lined, 76-mm (3-in.)-diam holes to lengths of ∿ 50 m (165 ft) with sufficient accuracy for most commercial applications. Horizontal glass-lined holes of this diameter and length could be useful as:

- Glass-lined drain holes for subsided mines.
- Glass-lined drain holes through diked areas to accelerate drainage after flooding.
- Injection holes for burning mines.
- Sealed, glass-lined inspection holes in mine faces or in dam abutments.
- Sealed, glass-lined inspection holes in suspected pollution areas.
- Underground utility conduits for telephone, gas, water, and television lines.
- Glass-lined holes for high-explosive shot emplacement.
- Drainage holes to stabilize road cuts and embankments.

System descriptions, preliminary design concepts, and detail component descriptions are presented in the following sections, along with indications of additional development programs required to provide subsystems that are not yet available for this versatile horizontal hole-melting device. Such a device will also

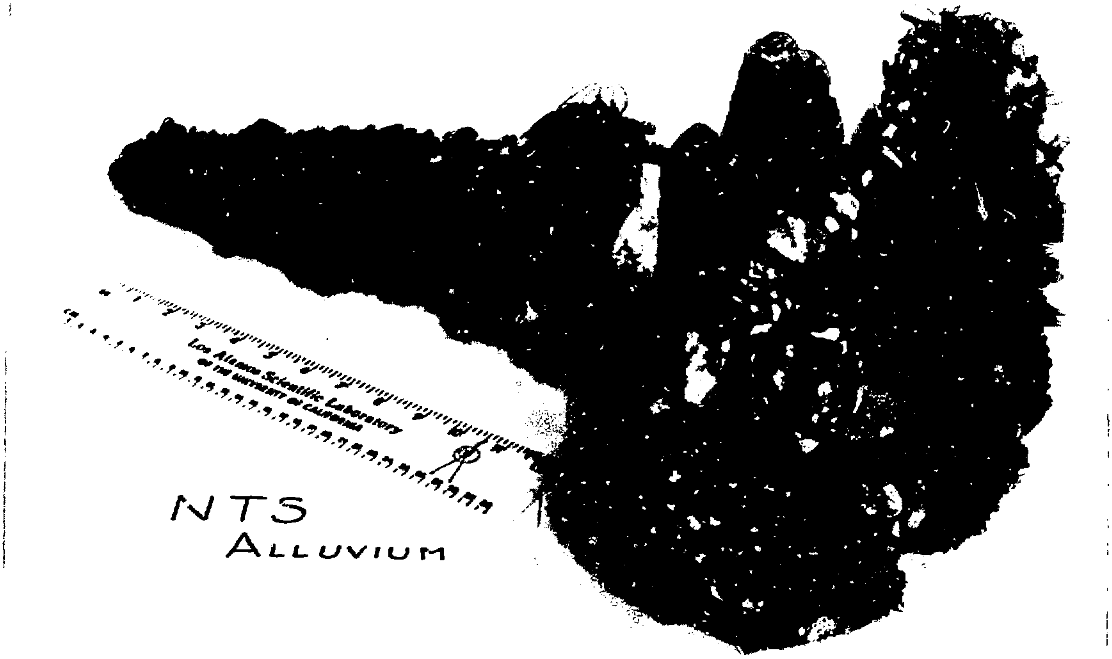


Fig. 8. External surface of glass-lined hole melted in dry alluvium.

provide necessary and valuable information for the development of the Geoprospector system.*

II. SYSTEM DESCRIPTION

The components of the proposed small-diameter horizontal Subterrene system, depicted in Fig. 9, are similar to those of the modularized rock-melting Subterrene demonstration unit shown in Fig. 4. These components include:

- A stem advancer, Fig. 10, that will continuously advance the stem by use of two independent hydraulic cylinders and remotely operated stem clamps.

- A dual-tube stem consisting of a flush outer steel tube, coupled in sections, and an insulated inner copper tube. These tubes provide the electric-power conductors to the heated penetrator, circulate coolant to the hole-forming assembly (HFA), and provide a force path to transfer the thrust to the advancing melting penetrator.

- Circulating, compressed-air coolant, to cool the stem, chill the glass-hole lining, and form small glass pellets (or rock wool) from the excess melt produced by a UEP. This excess melt debris is carried to the surface and ducted through the service head into a separating and collecting station. The return coolant from a consolidating penetrator is ducted directly into the ambient air.

- A quick-disconnect service head, Fig. 11, that connects the operational lines to the stem (i.e., electric power for the penetrator, coolant air for glass-forming and debris removal, and sensor and instrumentation leads).

- The HFA (hole-forming assembly), Figs. 12 and 13 , which is selected to fit the job requirement, can be assembled interchangeably from the following subcomponents:

*See Ref. 7, p. 19, for a brief description of this continuously coring tunnel prospecting device.

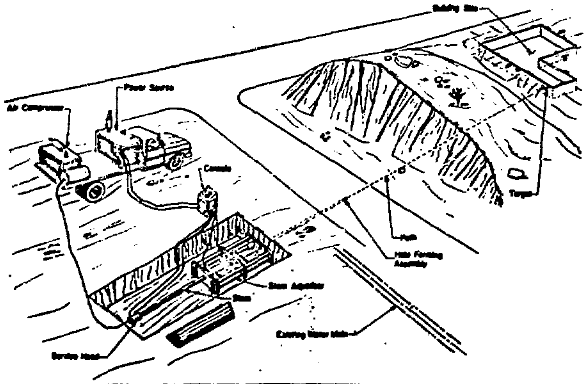


Fig. 9. Horizontal Subterrene melting a water service hole.

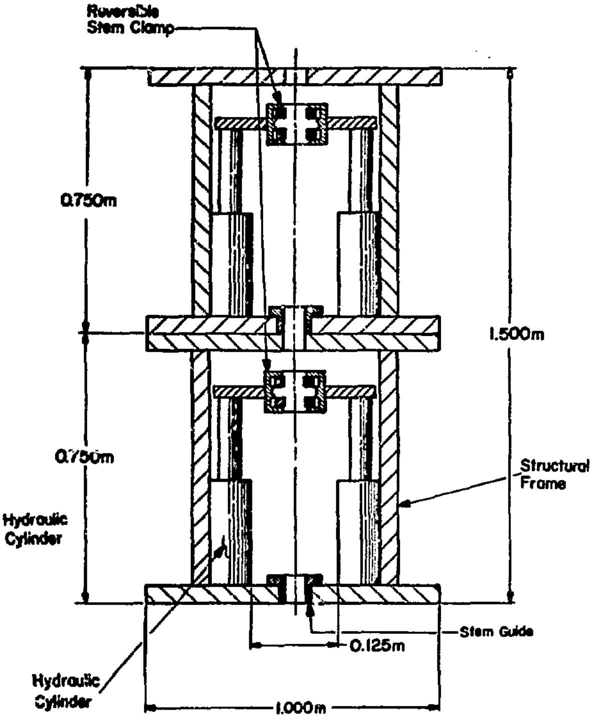


Fig. 10. Small-diameter horizontal Subterrene stem advancer.

- A heated penetrator, to melt rock or soil: A melting consolidating penetrator (MCP)[2], Fig. 14, is used in loose soils, alluvium, and low-density rock, and forms a glass lining; whereas a universal extruding penetrator (UEP)[5], Fig. 15, is used in dense or hard rock and produces rock debris.

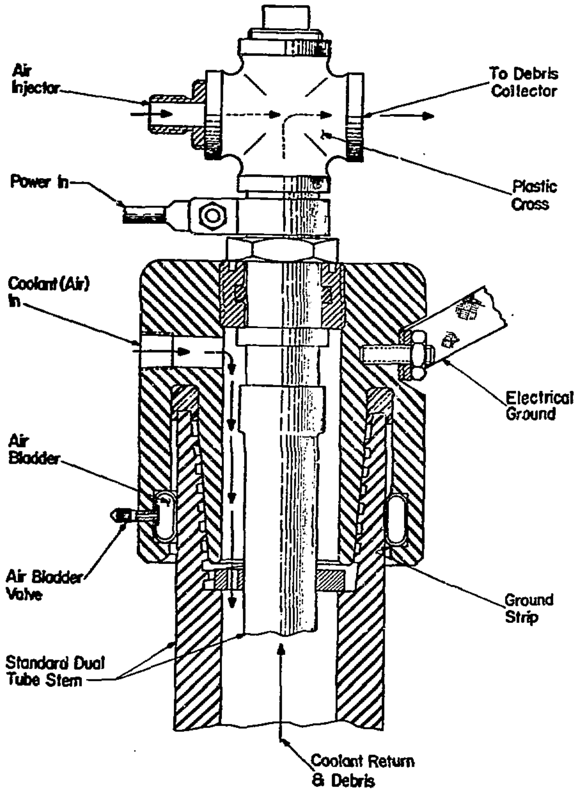


Fig. 11. Quick-disconnect service head.

- A glass former, attached directly to the penetrator, chills and forms the glass hole lining from the liquid melt. For the extruding penetrator, this unit also contains the components to chill the extrudate and to process the excess melt into removable debris.

- A centralizer, to hold the HFA on course.

- An alignment control section (ACS), to return the HFA to course when deviation is detected. The controlling force is oriented and applied from the surface control console.

- A deviation sensor (DS) or deviation indicator (DI), detects deviation of the HFA from the projected center line of the hole. Signals from the DS or DI are processed and displayed on the control console. The HFA can be made up in a variety of

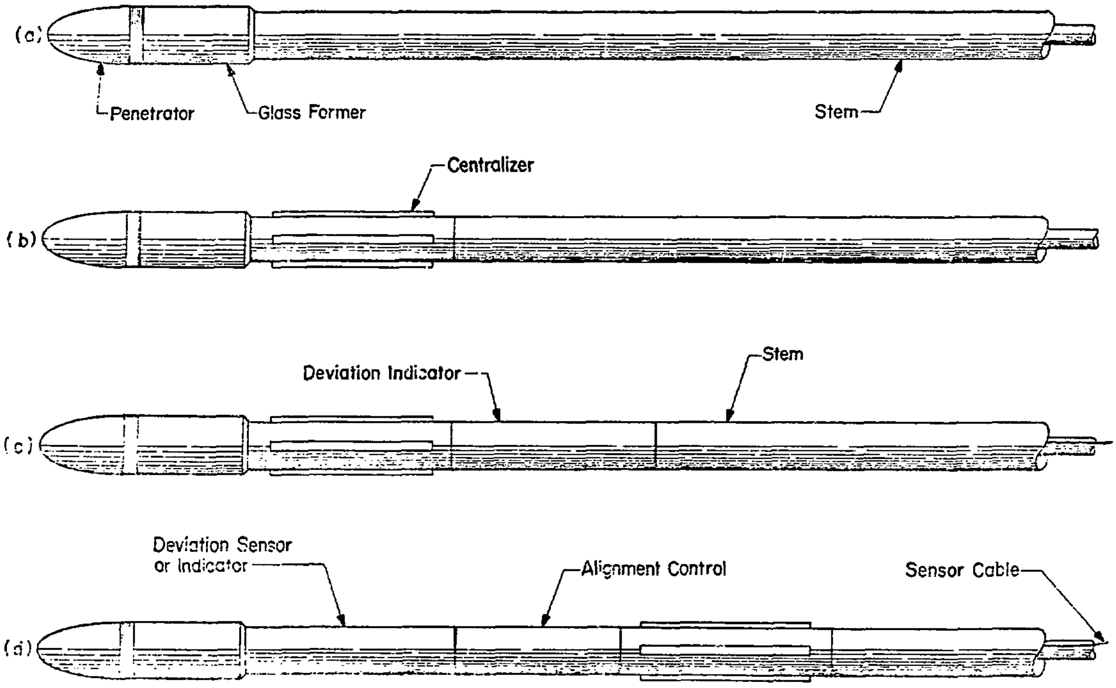


Fig. 12. Hole-forming assemblies: (a) simplest HFA-penetrator, glass former, and stem; (b) addition of centralizer; (c) additional deviation indicator; (d) complete assembly with alignment control.

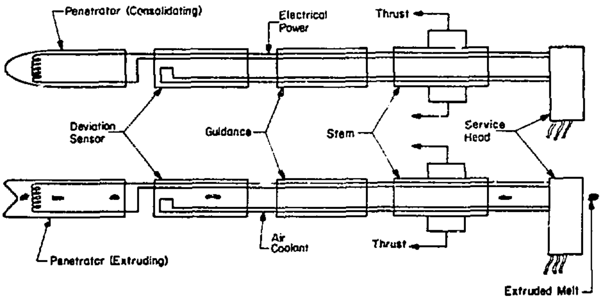


Fig. 13. System schematic for a horizontal consolidating and horizontal extruding Subterrene showing the required functions of the components.

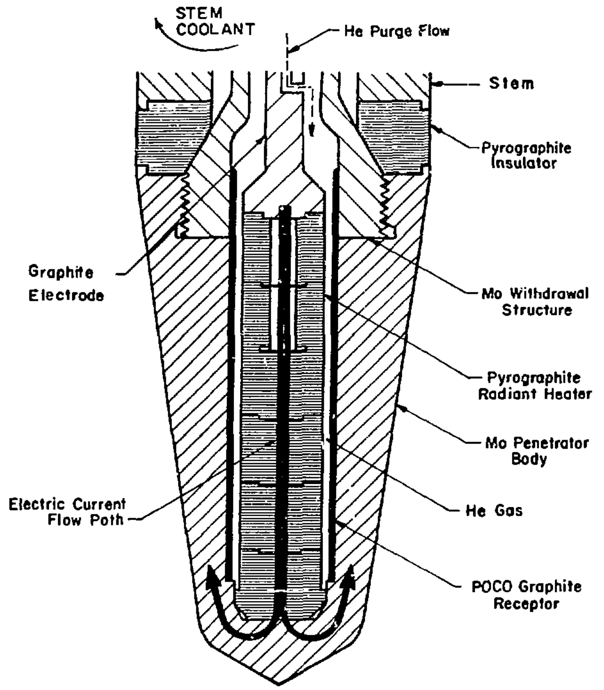


Fig. 14. Consolidating penetrator for loose soil and low-density rock.

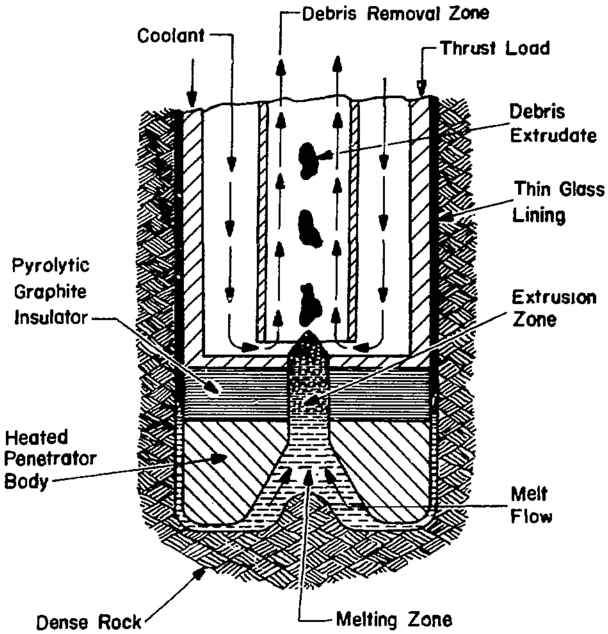


Fig. 15. Extruding penetrator for dense rock.

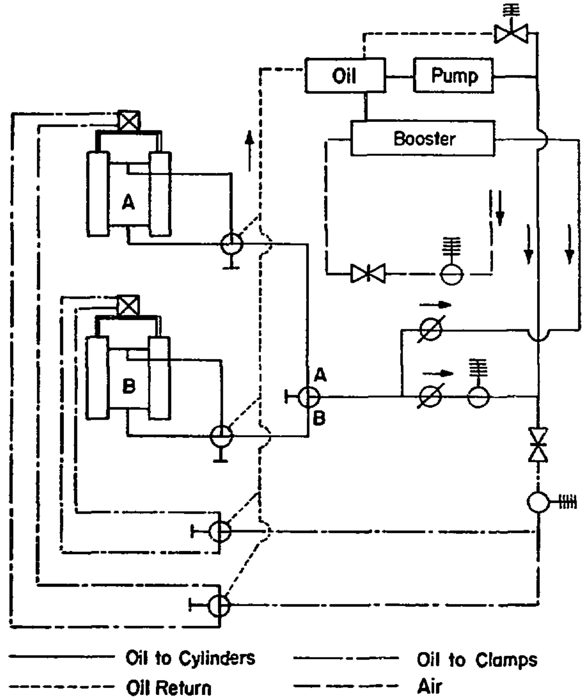


Fig. 16. Hydraulic and air-control circuits for operation of horizontal stem advancer.

configurations, as indicated in Fig. 12, to achieve the needed straightness for a given job.

• A complement of service units are needed to furnish electric power to the penetrators, sensors, and instrumentation; coolant air to the stem and glass-former; and hydraulic power to the stem advancer and stem clamps (Fig. 16). The coolant-air supply also powers an air-oil intensifier for emergency stem advance and retraction.

• A single control and instrumentation console will be provided for the necessary electric power, hydraulic and air controls, and for displays. Sensor displays and alignment-correction indications will also be shown on the console so that one operator can supervise the melting of a straight hole.

Note that the proposed horizontal rock-melting excavation system which forms the glass-lined holes in place can be assembled from various subcomponents to produce holes of varying straightness. For example, the hole-forming assembly can:

• Melt an accessible, glass-lined hole under obstructions or structures such as roads, highways, railroads, and canals where hole straightness is not a major factor. This can be accomplished with a simple HFA consisting of only a penetrator, glass former, and stem, as indicated in Fig. 12(a).

• Melt a very straight, accessible, glass-lined hole from an established point to intersect a target point with a maximum terminal deviation of two hole diameters or less. This will require a HFA equipped with a deviation sensor, a surface-operated alignment-control unit, and a sensor signal that can be displayed on and monitored from the control console by the operator [Fig. 12(d)].

The proposed system concepts, components, and specifications are detailed in the following sections.

III. SUMMARY OF SYSTEM SPECIFICATIONS

The following list summarizes the preliminary specifications for a horizontal hole-melting Subterrene system:

- Inside diameter of the glass lined hole, 76 mm (3 in.).
- Hole-length capability, 50 m (164 ft).
- Rate of penetration,
  - For a melt-consolidating penetrator (MCP) in loose alluvial soil up to 0.84 mm/s (2 in./min).
  - For a universal extruding penetrator (UEP) up to 0.42 mm/s (1 in./min).
- The two penetrator types are interchangeable, are electrically powered, and use circulating air for cooling and debris removal.
- The glass formers and hole sizers are integral parts of the penetrators.
- The maximum hole deviation is less than two diameters, but the system can be assembled in a simple version for less accurate operation.
- Deviation of the HFA from the projected hole center line is detected by the deviation sensor, and the amount of deviation is displayed on the control console.
- Directional control of the HFA is provided by a differential cooling system whose operation is regulated at the control console for high accuracy. Lesser straightness will be controlled by simple stem rotation.
- The hydraulic stem advancer-retractor is capable of continuous motion and is provided with remotely operated stem clamps. Hole alignment can be set within the range of $\pm$ 0.25 rad (15 deg) from the horizontal.
- The advancing stem will be a dual tube to transmit power and coolant and for debris removal when required. The stem will be flush externally and of sectioned lengths for ease of handling.
- Melting power is estimated at 15 kW, and total available power should be $\sim$ 25 kW.
- A quick-disconnect service head is included.
- The single control console will incorporate controls for air supply, hydraulic and electrical power; HFA deviation and amount of applied directional control; and instrumentation displays.
- The service units to be included are:
  - Air compressor.
  - Alternating-current generator, engine-driven.
  - Alternating current-to-direct current converter.
  - Hydraulic pump, motor-driven.
  - Air-oil hydraulic booster.
  - Light truck for mobility.
- Service leads and hoses are supplied as required.

IV. DESCRIPTION OF LASL-DEVELOPED AND COMMERCIALLY AVAILABLE SUBCOMPONENTS

A. General

This section describes components of the system that are either already developed or can be designed and assembled in a straightforward manner from commercially available products. The demonstration rig for 50-mm (2-in.)-diam penetrators has had excellent results in initial runs. Much of this simple, inexpensive modular rig (Fig. 4), can be used as the design base for the 76-mm (3-in.)-diam horizontal Subterrene. Other components have been thoroughly tested both in the laboratory and in field-test rigs. The alignment accuracy of the demonstration rig is sufficient for many anticipated uses of horizontal, glass-lined holes. In fact, by intermittently rotating the stem and the HFA of 50-mm (2-in.)-diam Subterrenes while melting vertical (Fig. 17) and horizontal (Fig. 18) holes, bores were produced that were straight to considerably better than two hole diameters in 16 m of hole length.

B. Description of Components

Specifically, the proposed small-diameter horizontal Subterrene system would consist of the components detailed below.

1. Stem Advancer

The stem advancer (Fig. 10) will advance the stem continuously with two independent, twin hydraulic-cylinder units and remotely operated stem clamps.

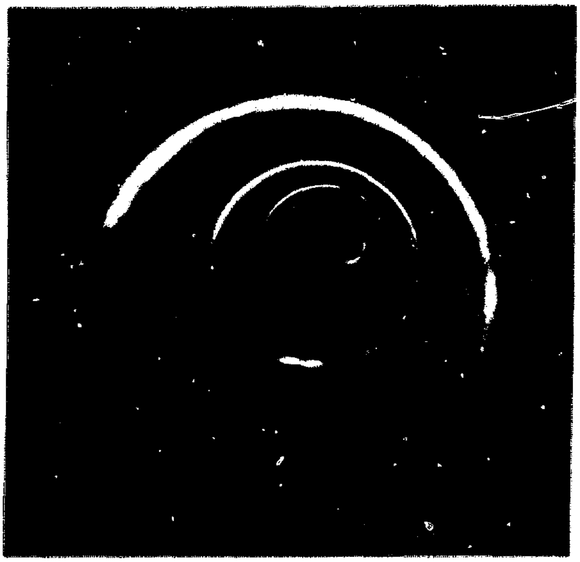


Fig. 17. Photograph showing degree of straightness in a glass-lined vertical hole.

Fig. 18. Photograph showing degree of straightness in a glass-lined horizontal hole.

- Normal operating pressure will be 6.9 MPa (1000 psi) for an advancing load per cylinder pair of 20000 N (4550 lb_f) and a retracting pull of 28000 N (6350 lb_f).

- Emergency operation will use four cylinders with a maximum of 13.8 MPa (2000 psi).

- The frame (head and base of each cylinder pair) will be adapted for fastening to anchor posts, and will be rigid at the above loads.

- Retraction time of a cylinder pair, with normal operating pressure using the hydraulic pump only, will be 20 $\pm$ 5 s.

2. Advancing Stem

- The dual-tube advancing stem (Figs. 11 and 12) will be similar to that used on the modularized, mobile rock-melting Subterrene demonstration unit.[6]

- The stem will be flush externally and slightly smaller in diameter than the HFA. The inner copper tube will have an inside diameter of $\sim$ 27.5 mm (1 $\frac{1}{16}$ in.).

- The operating temperatures of the stem are estimated to be less than 600 K. Materials used in stem construction near the HFA will have an operating life of 3000 h at this temperature. Additional stem sections will be constructed of conventional materials (low-carbon steel) and will operate at lower temperatures (400 K).

- The stem will be assembled in lengths of 1.5 m (5 ft) and 3 m (10 ft).

3. Service Head

The service head (Fig. 11) will provide a quick disconnect (and connect) of the surface supply lines to the stem (electric power, coolant, instrumentation, and debris removal).

4. Hole-Forming Assembly (HFA)

The hole-forming assembly (Fig. 12) for the simplified small-diameter horizontal Subterrene system would be assembled from the following.

- A heated penetrator will be selected for the anticipated rock or soil to be

encountered. Melting-consolidating penetrators 76 mm (3 in.) in diameter (Fig. 14) will be used for melting glass-lined holes in alluvium and low-density rock, and will be similar in design to the consolidating penetrators that have been developed. Universal extruding penetrators, which are interchangeable with melting-consolidating penetrators in the HFA, are used for melting in dense or hard rock. The design and construction of this type penetrator is also well advanced. Both penetrators will produce glass-lined holes of the same diameter.

- A glass former and hole sizer is attached directly to the penetrator. Because the melt is processed differently by the two types of penetrators, the glass former and hole sizer must be changed when the penetrator types are changed. The outside diameter varies with penetrator design, but is normally 0.15 mm (0.005 in.) larger than the penetrator diameter (at operating conditions).

- A centralizer -- essentially a section of advancing stem with longitudinal ribs built up to within 0.25 to 0.40 mm (0.010 to 0.015 in.) of the inside diameter of the finished glass lining -- is placed between the glass former-and-hole sizer and the forward end of the advancing stem.

5. Service Units

The service units required to operate the small-diameter horizontal Subterrene are:

- A skid-mounted air compressor rated at 200 ℓ/s (44 cfm) at 825 kPa (120 psi).

- A trailer-mounted, diesel-powered ac generator rated at 25 kW, with 60-cycle outputs of 17 kW at 220 V and 8 kW at 110 V.

- A solid-state ac-to-dc converter with 15 kW capacity, remotely controlled from the operator's console and powered by 60-cycle 220 V.

- The hydraulic supply is a constant-volume vane pump with a 3.8-kW (5 hp) 220-V 60-cycle motor. The output is 0.15 ℓ/s (2.4 gal/min) at 14 MPa (2000 psi) delivery pressure.

- The emergency hydraulic supply is furnished by an air-oil booster that provides 0.25 ℓ (16 in.^{3}) with a 300-mm (12-in.) stroke. The hydraulic pressure is 13.8 MPa (2000 psi) from the 55-kPa (80-psi) air supply.

- Power, coolant, and hydraulic leads are of conventional field-service weight to hook up the separate units.

6. Control Console

The electric, hydraulic, and air controls needed to operate the small-diameter Subterrene system will be grouped on the console (Fig. 16), so that a seated operator can control all operations. Instrument displays on the control console will include:

- The advancing or retracting load on the stem, reading in Pa and lbf/in.^{2}
- The hydraulic pressure available for advancing or retracting, reading in Pa and lbf/in.^{2}
- The hydraulic pressure on the stem clamps reading in Pa and lbf/in.^{2}
- The air pressure in use for cooling and debris removal, and the pressure available for the air-oil booster, reading in Pa and lbf/in.^{2}
- The advance rate of the stem, reading in mm/s and in./min.
- The accumulated advance, reading in m and ft.
- The amperage, voltage, and wattage of the heater circuit, and the heater resistance.

7. Mobilizing and Transport

The mobile small-diameter horizontal Subterrene system is transported on a one-ton truck.

The maximum length of a small-diameter glass-lined hole that can be successfully bored with this minimum system has not yet been determined. When increased hole length

and accuracy are required, a deviation sensor (DS) and an alignment-control section (ACS) will have to be added to the HFA. Development of these units is discussed in the next section.

V. DEVELOPMENT PROGRAM

A. Versatility of Hole-Forming Assembly

The subsystems (see Section III) of the small-diameter horizontal Subterrene system are, with three exceptions, either already in use or are commercially available. The three exceptions are:

- A deviation indicator,
- A deviation sensor,
- An alignment-control section.

The deviation indicators and deviation sensor subsystems can be adapted from available instrumentation and electronics, but the alignment-control unit will require a development program and is unique to the proposed horizontal hole-forming system.

These additional subsystems allow a planned programming of hole-forming assemblies (HFAs) for jobs requiring varying levels of hole straightness and completion accuracy. Desired levels of performance can be achieved by assembling HFAs in the following configurations:

Assembly A. A heated consolidating or extruding penetrator (depending on geology and density of the formation) is used with an advancing stem [Fig. 12(a)] to melt, e.g., horizontal, shallow surface drain holes; equipment-placement holes; and utility conduits having moderate tolerances for installation misalignment. The course of the melted hole is controlled by periodic partial rotation of the advancing stem to equalize deviations caused by eccentricity of the assembly.

Assembly B. A heated penetrator, centralizer, and advancing stem [Fig. 12(b)] can be used to extend the length of holes melted with alignment requirements similar to those of Assembly A. The centralizer holds the heated penetrator on course, allowing higher stem loads, increased penetration rates, and longer controlled penetration. Periodic partial rotation is again used to equalize deviations due to assembly eccentricity. The centralizer assists in the control of penetrators over longer and more accurate runs such as utility conduits for high-voltage supply and gravity-sewer connectors.

Assembly C. This system consists of a heated penetrator, centralizer, deviation indicator*, operator signals, and advancing stem [Fig. 12(c)]. In addition to providing the increased hole-alignment capability of Assembly B, the operator is alerted whenever the HFA deviates by a preset amount from the proposed hole center line. By indicating to the operator the quadrant of deviation (viewed down the hole) the operator may initiate a course correction by quadrant rotation of the advancing stem rather than by periodic partial stem rotation. Continued quadrant deviation would signal a mechanical cause, either a change in geologic formation (boulders) or stem deformations.

Assembly D. A heated penetrator, deviation sensor (or deviation indicator), alignment-control section, centralizer, operator signals, and advancing stem [Fig. 12(d)] are assembled. This unit can track the deviation of the HFA assembly from the projected center line of the hole in terms of azimuth and bearing, and display this information on the control console. The alignment-control section allows the operator to turn the HFA toward the projected hole center line. This assembly also allows the operator to follow and to control the HFA in a predetermined deviated path. Such positive control of the hole-forming assembly will increase the capacity of the small-diameter horizontal Subterrene system for

---

*The deviation indicator is used for quadrant deviation signal and control.

following critical paths or intersecting small targets.

B. Development of Attitude-Control Sensors

Several approaches to the development of sensors, deviation indicators, and alignment-control systems are being investigated. The deviation indicator (DI) shown conceptually in Fig. 19 will flash a light on the control console to alert the operator that the hole-forming assembly has deviated a predetermined amount in a given quadrant (viewed from the stem-advancer end). The signal is generated when the cantilevered section of the inner tube is contacted by the outer housing after a predetermined deflection. This approach is similar to that of a simple torque-wrench indicator.

The development of a deviation sensor (DS) can choose among several possibilities:

- Laser optical systems are currently in use for aligning tunnel-boring machines; however, although the HFA will probably deviate more than one diameter in a guidance-control cycle and although the use of a laser is therefore questionable, these systems will be reviewed for possible adaptation of the HFA.

- Inertial guidance systems are widely used for navigation and attitude-control systems. These systems will also be reviewed.

- Gyrostabilizers are extensively used for navigation, attitude control, and bore-hole surveying.[9-11] They will be reviewed for possible application for inclusion in the HFA. A preliminary review indicates that hole size and length of time to melt a hole may restrict their use to attitude and directional control.

- Surface triangulation of a seismic source in the HFA may be a method to determine hole deviation. Results to date have not been promising, but a state-of-the-art review should reveal whether sufficient progress has been made to accurately track an HFA.

- Triaxial dc magnetometers are in use for attitude-sensing and navigation. In one current application[12,13] the device is following the path of a directional drilling tool and signals any deviations of a bore hole in conventional oil, gas, and water drilling, or in guiding the drilling of life-support holes to trapped miners. A review of this system will determine its adaptability for HFA use.

C. Examples of Deviation Sensors

Two possibilities discussed above are used to illustrate the sensor section of the HFA, the surface display, and the operator's use of the display to initiate corrective action (see Figs. 19, 20, and 21). An open-loop sensing and control system is considered adequate for the length of hole specified in Section III.

The relatively simple deviation indicator shown in Fig. 19 can alert the operator if the HFA is deviating in a given quadrant. A section of the inner tube is built as an independent cantilever beam by using a flexible bellows connection. Four contacts are placed around the inner tube with a small initial standoff clearance from the tube. Deflection of the outer housing, forced by hole deviation, will cause contact between the inner tube and one of the four contacts. Closing of the contact will light up a corresponding signal on the control console. Corrective action can then be initiated either by rotating the advancing stem to equalize mechanical alignment, or by using an alignment-control section in the HFA. Physical orientation of the advancing stem is maintained by aligning and clamping fiducial protractors that are attached to the stem section at the stem advancer.

A triaxial magnetometer sensor can detect rotation of its axes relative to an initial orientation. Figure 20 shows schematically the use of a triaxial magnetometer as the deviation sensor for a

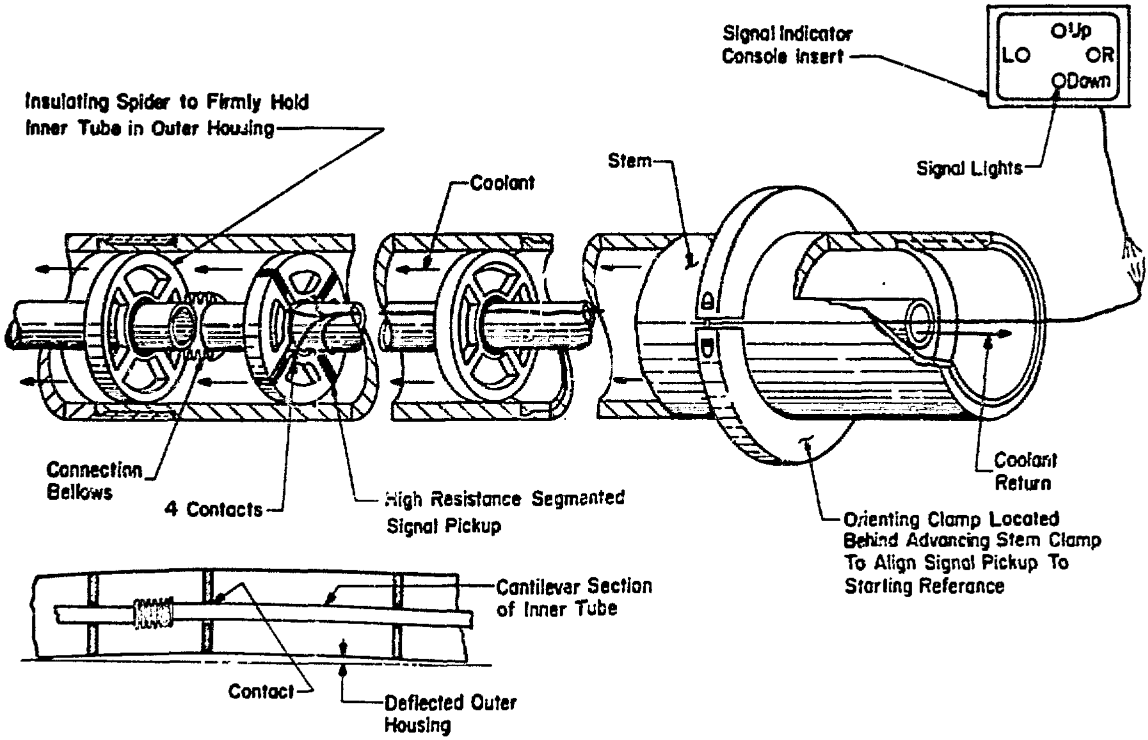


Fig. 19. HFA deviation indicator.

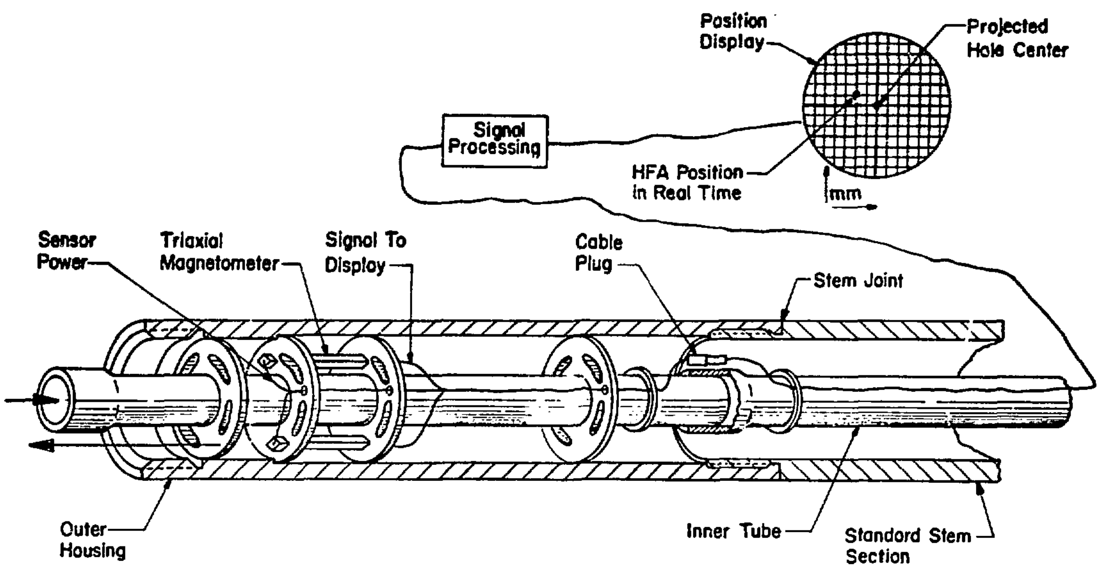


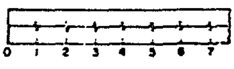
Fig. 20. Triaxial magnetometer deviation sensor.

small-diameter horizontal Subterrene. The power to the sensor and the return signals is carried in a multiple-channel cable to a signal processor. After processing, the change in position of the HFA is displayed on an oscilloscope screen in the control console. A computer can be used to plot continuously the excursions of the HFA from the hole center. However, penetration rates are sufficiently slow to determine HFA excursions by hand-calculation (Fig. 21), eliminating computers and plotters.

D. Alignment Control Section (ACS)

One method of applying a realigning turning force to a heated penetrator while melting a hole is to selectively cool one side of the outer housing of a section of the hole-forming assembly (HFA). This can be accomplished by diverting the inlet-coolant flow as shown in Fig. 22. A gravity-activated coolant-channeling valve, rotationally aligned with the stem, makes it possible to select the azimuthal location of the cooled side on the advancing housing and thus to apply directive force to the HFA from the control console. Construction and operation of such a device are outlined in Fig. 22. The gravity-activated coolant-channeling valve is an eccentrically weighted disk that is free to rotate on frictionless ball bearings within the outer tube of the alignment-control section. Thus, if the stem is rotated at the stem advancer end, the coolant-channeling valve retains its relevant position with respect to the melted hole. In addition to a passage for the inner coolant- (and debris-) return tube, the coolant-channeling valve has two ports: one, labeled A in Fig. 22, is for total coolant bypass when no corrective force is required. The second passage, B, is used to selectively channel the coolant flow into Coolant Passage C to provide an azimuthally chilled portion of the outer tube. This cooler region will tend to cause a deflection of the tube, which, in turn, will generate a moment to act on the penetrator (see Appendix).

Immediately downstream of the coolant-channeling valve is a bulkhead with five ports. Port A is for normal flow bypass and is spaced between Ports E and D, two of the



HFA Deviation, mm								
Reading					Total			
No.	Up	D	L	R	Up	D	L	R
1	10		20		10		20	
2		30		30		20		30
3		50		40		80		70

Hand Calculation

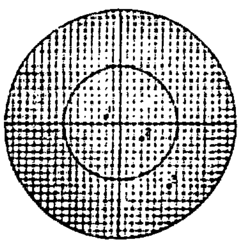


Fig. 21. HFA deviation plot board.

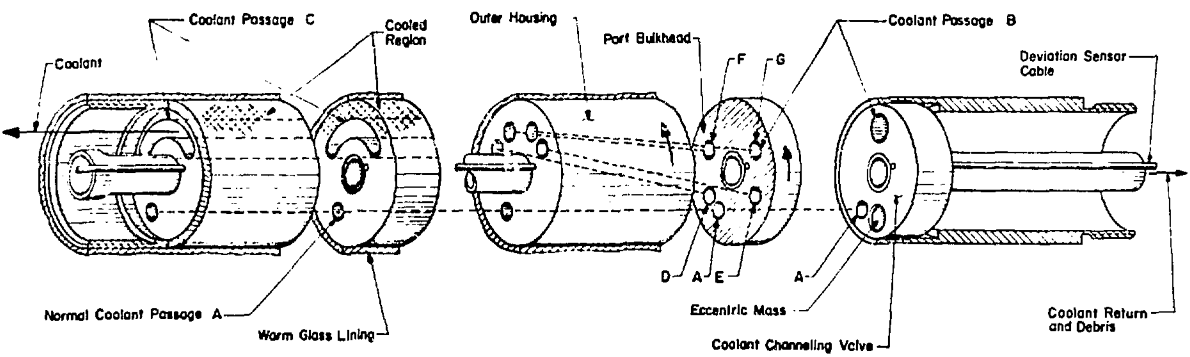


Fig. 22. Alignment control section.

four ports (D, E, F, and G) spaced 90 deg apart for selective flow control. These four ports are led through the outer housing so that all four connect with Coolant Passage C. Coolant Passage C extends along one side of the outer housing for a distance sufficient to produce the required turning force when coolant is ducted through.

For normal flow bypass, the stem is rotated until Port A in the coolant-channeling valve is in line with Port A in the bulkhead with Coolant Passage C facing up. This position is marked at the stem-advancer end with a fiducial protractor clamp placed on the advancing stem. When deviation of the heated penetrator from the center line of the hole is detected and shown on the surface display (Fig. 20), the operator can make the necessary correction. For example, if the display shows left deviation, the operator rotates the stem 90 deg to the right, so that the coolant passage, C, is moved to the right-hand side of the hole and Port B is aligned with Port G in the bulkhead; Port A is blanked off. Differential cooling of the outer housing will turn the HFA back toward the hole center line, at which time the coolant is returned to normal bypass flow by returning the stem-position indicator at the advancer to the Passage-C <u>up</u> position.

Other systems of alignment control can be visualized, such as having three or four equally spaced coolant passages and adjusting the coolant flow in the HFA with remotely controlled valves. The smallness of a 76-mm-diam hole and the restricted volume available for HFA control suggested the concept of a gravity-activated coolant-channeling valve for alignment control.

VI. OPERATIONS

The components listed and described in Sections III and IV will be selected or designed to be modular and interchangeable. The HFA can be assembled in any of the following configurations:

- Consolidating penetrator with stem centralizers.
- Consolidating penetrator with deviation indicator and stem centralizers.
- Consolidating penetrator with deviation indicator, stem centralizers, and alignment-control section (ACS).
- Extruding penetrator with any of the above options.

The correct HFA will be selected to fit the individual job requirements, including the desired accuracy in the location of the melted hole. When maximum accuracy is desired, the center line of the hole can be established by conventional methods, e.g., by usual land-surveying as indicated in Fig. 23.

The stem advancer and support equipment are then moved to the starting point of the hole. The HFA (and a section of stem) are clamped in the stem-gripping clamps. A transit and stadia rods are used to check alignment of the bearing and the inclination angle determined by the survey. Adjustments are made by blocking and wedging the stem-advancer base. The support equipment is located as the terrain permits, with the control console close to the stem advancer. All equipment is started, operated, and serviced according to the manufacturer's instructions. Service lines are attached, and melting of the hole is started.

Stem-gripping clamps on the pairs of advancing hydraulic cylinders are used alternately: While one clamp is advancing, the other is retracting in preparation for a continuous advancing stroke. All functions related to advancing and retracting the stem and the HFA are controlled from the console, with the exception of adding (or removing) additional stem sections.

When additional stem is required, the operator:

- Reduces power and coolant flow to zero.

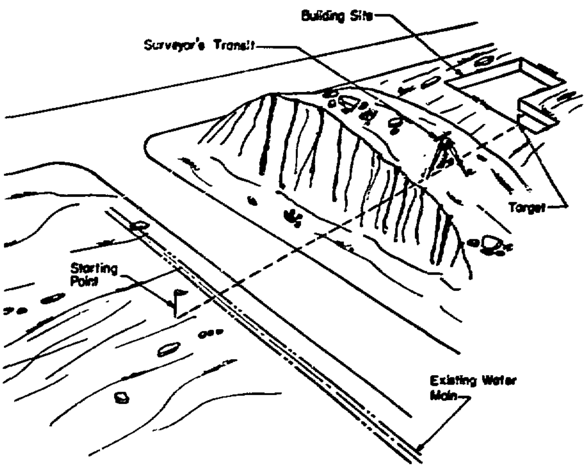


Fig. 23. Establishing the hole center line.

- Stops advancing pressure and releases the rear stem-advancing clamp, returning this clamp to the full-out position.
- Releases bladder pressure in quick-disconnect service head (QDSH).
- Slips off QDSH and unplugs signal leads.
- Adds stem section and tightens connection after plugging-in signal leads.
- Slips on QDSH, replugs signal leads to console and repressures bladder.
- Raises power and coolant flow to previous values.
- Regrips stem and applies previous load.

The stem is retracted (when the hole is finished or for any other reason) with the following steps; the operator:

- Reduces stem load to zero.
- Reduces power to zero.
- Reverses thrust load to retract mode.
- Maintains coolant flow until the stem pulls freely (stem drag only).
- Shuts off retraction force.
- Reduces coolant flow to zero and removes QDSH.
- Pulls out stem until the next stem connection is accessible. Loosens and unscrews connection.
- Unplugs signal leads and racks stem section.
- Continues the two previous steps until HFA is out of hole.
- Secures all equipment.

If required, the hole can then be surveyed by visual observation or instrumentation to evaluate straightness, glass-casing thickness, etc.

VII. CONCLUSIONS AND DISCUSSION

The development of small-diameter Subterrene rock-melting penetrators has reached the stage where the design of a 75-mm (3-in.)-diam system for forming horizontal, glass-lined holes is possible. Contacts with utility companies and requests for information from industrial firms have indicated the need for such a device.

A comprehensive development program would have to address two major areas:

- The development of an alignment-control subsystem.
- The conduct of an economic study and a market survey.

A most attractive feature of horizontal hole-melting Subterrene systems is the capability of varying the accuracy of hole straightness to match job requirements. This is achieved by including or omitting the appropriate sections in the hole-forming assembly.

The information and experience gained from the development and commercialization of the horizontal hole-melting system will be of value to other Subterrene system developments. The benefit derived can be anticipated to be:

- Field data on service life and reliability of components, particularly penetrators.
- Extension of the technology to the melting of holes with curved paths.
- Experience that will lead to horizontal hole-melting systems with increased diameter and range.
- Adaptation of the perfected alignment-control scheme to vertical hole-melting systems.

The successful development of the horizontal, small-diameter melting system can contribute significantly to further developments in subsequent Subterrene programs. This influence is shown schematically in Fig. 24. In addition to valuable experience and direct data on service life and reliability obtained in commercial applications, the effort will help in forming a scientific and engineering basis for design and optimization of subsequent devices. The very small-diameter melting penetrators (see Fig. 25 for an early prototype) can find uses such as punching holes in concrete or masonry walls, but difficult miniaturization problems will need to be solved if long holes are to be made. In addition, the experience with 75-mm-diam units will contribute to the development of a Geoprospector,[14] illustrated in Fig. 26, and will offer early inputs to the solutions of position sensors and guidance problems.

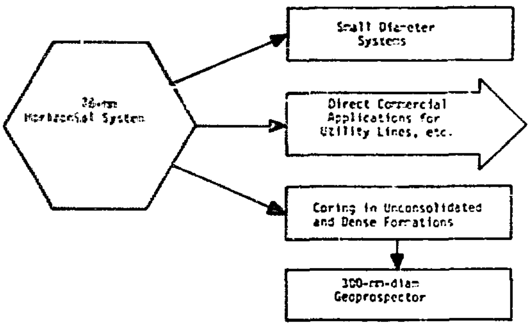


Fig. 24. Effect of 75-mm-diam horizontal Subterrene system on subsequent research and development.

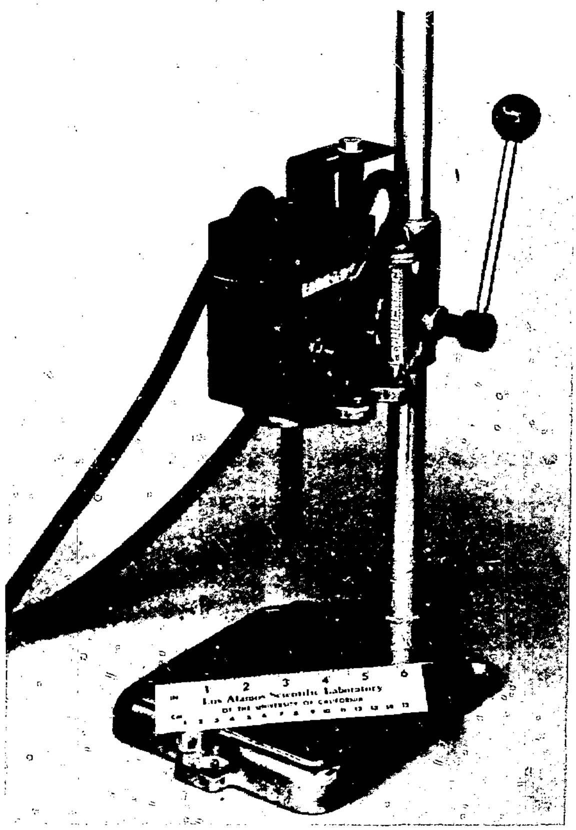


Fig. 25. Early prototype of 10-mm-diam rock-melting subterrene.

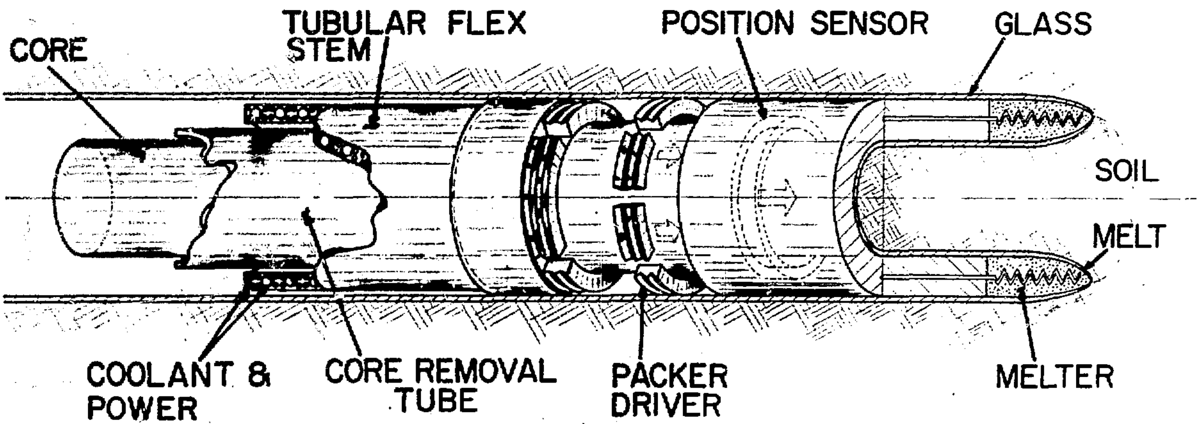


Fig. 26. Coring Geoprospector with position sensor and directional guidance systems capability.

REFERENCES

1. E. S. Robinson, R. M. Potter, B. B. McInteer, J. C. Rowley, D. E. Armstrong, R. L. Mills, M. C. Smith, Editor, "A Preliminary Study of the Nuclear Subterrene", Los Alamos Scientific Laboratory report LA-4547 (April 1972).

2. J. W. Neudecker, "Design Description of Melting-Consolidating Prototype Subterrene Penetrators," Los Alamos Scientific Laboratory report LA-5212-MS (February 1973).

3. R. E. Williams and J. E. Griggs, "Use of the Rock-Melting Subterrene for Formation of Drainage Holes in Archeological Sites," Los Alamos Scientific Laboratory report LA-5370-MS (August 1973).

4. R. G. Gido, "Description of Field Tests for Rock-Melting Penetration," Los Alamos Scientific Laboratory report LA-5213-MS (February 1973).

5. J. W. Neudecker, A. J. Giger and D. E. Armstrong, "Design and Development of Prototype Universal Extruding Subterrene Penetrators," Los Alamos Scientific Laboratory report LA-5205-MS (March 1973).

6. R. E. Williams, "Development of a Modularized Mobile Rock-Melting Subterrene Demonstration Unit," Los Alamos Scientific Laboratory report LA-5209-MS (March 1973).

7. D. L. Sims, "Identification of Potential Applications for Rock-Melting Subterrenes," Los Alamos Scientific Laboratory report LA-5206-MS (February 1973).

8. James Paone, "Horizontal Holes for Underground Power Lines," Proc. Tunnel and Shaft Conf., Minneapolis, MN, May 15-17, 1968, pp 93-113.

9. R. L. Waters, The Electro-Mechanics Company, P. O. Box 1546, Austin, TX, letter communications, April 1973.

10. Sperry-Sun Well Surveying Catalogue 723, "Magnetic Steering Tool", p. 4049. Sperry-Sun Well Surveying Co., P. O. Box 36363, Houston, TX 77036

11. Humphrey, Inc. Bulletin FG-1270, "Surveyor Bore Hole Directional Systems", Humphrey, Inc., 2805 Canon St., San Diego, CA 92106

12. C. Ishan, Scientific Drilling Control, 4040 Campus Drive, Newport Beach, CA, personal communication, April 1973.

13. L. A. Rubin, "New Survey Systems for Drilling," Telcom, Inc., McLean, VA 1971.

14. J. W. Neudecker, "Conceptual Design of a Coring Subterrene Geoprospector", Los Alamos Scientific Laboratory report in preparation.

APPENDIX

ANALYSIS OF PROPOSED ALIGNMENT CONTROL SCHEME

The parameters affecting the design and performance of the alignment control section (ACS) proposed in the main body of the report can be derived by reference to Fig. A-1. The temperature difference established across the diameter of the ASC by the diverted coolant will induce a curvature in the housing given by

$$\frac{1}{\rho} = \frac{\bar{\alpha}\ \Delta T}{D}, \qquad \text{(A-1)}$$

if the unit is free to deflect [Fig. A-1(a)],
where ΔT = effective temperature difference;
ρ = radius of curvature
$\bar{\alpha}$ = mean coefficient of thermal expansion
D = diameter of the housing.

Typical values for the projected design and materials are:

$\bar{\alpha} \cong 6.0 \times 10^{-6}$, K^{-1}
D = 75 mm ≡ 0.075 m
ΔT = 100 K.

The curvature and radius of the deflected path are

$$\frac{1}{\rho} = \frac{6.0 \times 10^{-6} \times 10^{8}}{0.075} = 0.008\ m^{-1}$$

$$\rho = 125\ m.$$

Therefore, if the length, L, of the ACS unit is 1.0 m, the derivation at the end of the unit will be given by

$$\Delta = \frac{\bar{\alpha}\ \Delta T}{2D} = 0.0033\ m \equiv 3.3\ mm.$$

If the ASC is initially rigidly fixed by a centralizer section at one end and the penetrator at the other end, Fig. A-1(b), it will exert a moment given by

$$M = \frac{E\ I}{\rho}, \qquad \text{(A-2)}$$

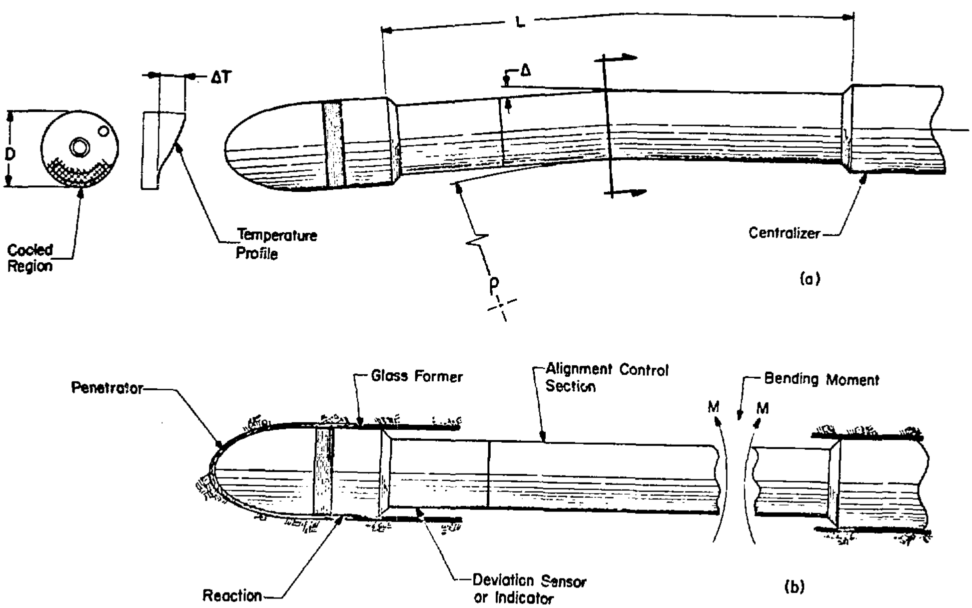
where

E = elastic modulus of the material from which the ACS is constructed
I = area moment of the ACS cross section.

Taking E = 207.0 GPa ($30 \times 10^6\ lb_f/in.^2$), the data above, and combining Eqs. (A-1) and (A-2), the moment (M) and induced stress (σ) are:

$M = 2.6 \times 10^3$ N·m (2.27×10^4 in. lb_f)
σ = 62 MPa (9.000 $lb_f/in.^2$).

This moment is of sufficient magnitude to induce the required path deviation while generating only low stresses in the hole-forming assembly.



EE:306(110)

Fig. A-1. Proposed alignment control scheme.

DEPARTMENT OF THE ARMY
ENGINEER RESEARCH AND DEVELOPMENT CENTER, CORPS OF ENGINEERS
WATERWAYS EXPERIMENT STATION, 3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

8 April 2009

Office of Counsel

SUBJECT: Freedom of Information Act Request No. 09-05

Mr. John Greenewald, Jr.

Dear Mr. Greenewald:

In response to your FOIA request dated March 18, 2009, enclosed is the information you requested. There will be no charges associated with this request. If you have any questions, please feel free to contact me at the address above or at telephone number (601) 634-2757.

Sincerely,

Lewis H. Burke
FOIA Officer

Enclosures

MISCELLANEOUS PAPER E-74-5

USE OF THE SUBTERRENE FOR MILITARY DRILLING APPLICATIONS

Major Lynn C. Webster

October 1974

U. S. Army Engineer Waterways Experiment Station

Explosive Excavation Research Laboratory

Livermore, California

Approved for public release; distribution unlimited

Printed in USA. Available from Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314 or National Technical Information Service, U. S. Department of Commerce Springfield, Virginia 22161

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MP E-74-5	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) USE OF THE SUBTERRENE FOR MILITARY DRILLING APPLICATIONS		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Lynn C. Webster MAJ, CE		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Engineer Waterways Experiment Station Explosive Excavation Research Laboratory Livermore, CA 94550		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 4A162121A859 Task 05; Work Unit 014
11. CONTROLLING OFFICE NAME AND ADDRESS Office of the Chief of Engineers WASH DC 20314		12. REPORT DATE October 1974
		13. NUMBER OF PAGES 27
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release: distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Drilling
Rock Drilling
Subterrene
Rock Melting Techniques
Explosive Emplacement
Subsurface Exploration

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The subterrene melts holes through soil and rock by means of a high temperature penetrator. Its capabilities include precision drilling, simple operation, a natural casing of the drill hole (in the form of a glass lining produced during penetration), long life of the penetrator (the life of the subterrene penetrator far exceeds that of the rock bit), and environmental advantages (the loud noise and dust produced by rotary and percussion drills do not exist at a subterrene site). On the other hand, the cost of subterrene operations is a definite limitation; it is very high compared with that of conventional drilling.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20., Continued

An analysis of military drilling requirements reveals that additional serious limitations arise when the subterrene is considered for military applications.

It is concluded that, in its present configuration and even with its projected capabilities, the subterrene does not meet a significant number of the drilling requirements of the Army.

MISCELLANEOUS PAPER E-74-5

USE OF THE SUBTERRENE FOR MILITARY DRILLING APPLICATIONS

Major Lynn C. Webster

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
EXPLOSIVE EXCAVATION RESEARCH LABORATORY
LIVERMORE, CALIFORNIA

MS. date, October 1974

PREFACE

The U. S. Army Engineer Waterways Experiment Station (USAEWES) Explosive Excavation Research Laboratory (EERL) evolved from the organization originally known as the USAE Nuclear Cratering Group (NCG), which was established in 1962. The period between 1 August 1971 and 21 April 1972 was a transition period during which the laboratory was known as the Explosive Excavation Research Office (EERO).

EERL conducts research in the areas of nuclear and high explosive effects with emphasis on the use of explosives for creation of military barriers to armor movement and large scale construction excavation. Closely related to this explosive excavation work is a concern with the ability of Corps of Engineers personnel to optimally place explosives for specific applications. Thus, there exists an extensive interest in improving the capability to drill large-diameter holes to reasonable depths. This work was performed as a result of this interest and funding supplied by the Inhouse Laboratory Independent Research Program of the Waterways Experiment Station.

The Director of WES during the preparation of this report was COL G. H. Hilt and the Director of EERL was LTC R. R. Mills, Jr.

ABSTRACT

The subterrene melts holes through soil and rock by means of a high temperature penetrator. Its capabilities include precision drilling, simple operation, a natural casing of the drill hole (in the form of a glass lining produced during penetration), long life of the penetrator (the life of the subterrene penetrator far exceeds that of the rock bit), and environmental advantages (the loud noise and dust produced by rotary and percussion drills do not exist at a subterrene site). On the other hand, the cost of subterrene operations is a definite limitation; it is very high compared with that of conventional drilling. An analysis of military drilling requirements reveals that additional serious limitations arise when the subterrene is considered for military applications.

It is concluded that, in its present configuration and even with its projected capabilities, the subterrene does not meet a significant number of the drilling requirements of the Army.

ACKNOWLEDGMENTS

The preparation of this report was made possible by the contributions of several people. The author desires to acknowledge the assistance of MAJ Richard L. Gates and SP4 Jon Morishita for their assistance in collecting data on the subterrene and its capabilities. Appreciation is also expressed to Drs. J. C. Rowley, C. A. Bangston, and R. J. Hanold, and to Mr. R. E. Williams, all of Los Alamos Scientific Laboratory, for their assistance in providing reports on development progress and participation in discussions on the subterrene.

CONTENTS

	Page
PREFACE	ii
ABSTRACT	iii
ACKNOWLEDGMENTS	iv
I. INTRODUCTION	1
A. Background	1
B. Scope	1
II. ARMY DRILLING REQUIREMENTS AND CAPABILITIES	2
A. Drilling Requirements	2
1. Combat Support	2
2. Construction Support	2
3. Utilities	3
B. Drilling Capabilities	3
C. Proposed Procurement	3
III. DEVELOPMENT OF THE SUBTERRENE CONCEPT	5
A. History	5
B. Concept and Devices	5
C. Support Equipment	7
D. Evaluations	7
E. Future Plans	9
IV. CAPABILITIES AND LIMITATIONS OF THE SUBTERRENE FOR DRILLING APPLICATIONS	10
A. Penetration Rate	10
B. Support Requirements	10
C. Costs	11
D. Special Advantages	12
V. EVALUATION OF THE SUBTERRENE FOR MILITARY DRILLING APPLICATIONS	14
VI. CONCLUSIONS	16
REFERENCES	17
BIBLIOGRAPHY	18

USE OF THE SUBTERRENE FOR MILITARY DRILLING APPLICATIONS

I. INTRODUCTION

A. Background. U. S. Army Engineers, like their counterparts in industry, are continuously seeking new ways to increase their capability to excavate soil and rock. Unlike his civilian counterpart, the Army Engineer has as his main purpose for this search the improvement of the quality of the support he is able to give to the fighting soldier. The types of missions included in this support vary from the excavation of individual fighting positions to the creation of effective obstacles and beyond. Construction is also included in these missions; however, responsiveness to the front-line soldier's needs is of primary importance. The Army Engineer has been severely restricted in efforts to improve his capabilities by the absence of a truly effective method for rapidly drilling holes in soil and rock. Therefore, he is vitally interested in new drilling techniques.

One such technique now being developed at the Los Alamos Scientific Laboratory (LASL) employs a tool called the subterrene. The subterrene melts holes through soil or rock with a high temperature penetrator. Tests have demonstrated that the concept is workable and may well prove to be an extremely effective drilling method.

B. Scope. This report will review current and anticipated military drilling requirements, briefly describe the subterrene, and evaluate the apparent suitability of the subterrene for meeting these requirements. Since subterrene development is still in the active stage, the evaluation of its capabilities must, by necessity, reflect the anticipations of its developers. In some cases, these concepts have not yet been proven.

II. ARMY DRILLING REQUIREMENTS AND CAPABILITIES

A. Drilling Requirements. For discussion purposes, Army drilling requirements have been divided into three distinct categories:

1. Combat Support. Combat support represents those operations specifically oriented toward assisting the front-line combat soldiers in performance of their fighting mission.

Although several techniques have been developed to assist the soldier in preparing fighting positions, none has proven entirely adequate. Most require excessive installation time or are at least partly restricted by certain geologic conditions. A workable large-hole drilling capability could do much toward improving this situation. Such a capability would be especially effective in rapidly preparing secondary or alternate positions during defensive and retrograde operations. The reduction in manpower required to perform such work would greatly increase the forces available to the combat commander.

One of the most useful combat support tools available is the barrier or obstacle to enemy armor movement. Many natural obstacles exist in most terrains; however, the combat engineer is called upon to tie these natural obstacles together with artificial obstacles created at selected locations and selected times. An effective obstacle of this type is the explosively produced crater. Both nuclear and high explosive sources can be used to produce such craters. At present, only nuclear cratering detonations are available for producing large obstacles. High explosive cratering is generally limited to production of small road craters that will certainly slow and harass enemy armored forces but will not present a serious obstacle to their movement. An active research program is evaluating the possible military use of bulk explosives commonly used in the commercial mining and quarrying industries. These explosives would allow the combat engineer to produce large craters using large quantities of explosives. In order to gain optimum use of both nuclear devices and these new bulk explosives, a capability for drilling large, relatively deep emplacement holes must be provided. Only then can cratering charges be placed at sufficient depth to optimize crater production.

2. Construction Support. The construction support capabilities of combat and construction engineers can be greatly improved by expanding the ability to drill holes more effectively in soil and rock. Exploratory drilling can do much toward improving construction designs. Current capabilities are seriously limited. Larger hole size, both diameter and depth, is needed to allow expansion of foundation construction. In many locations, the ability to install large concrete caissons would ease the construction of large structures, such as petroleum storage tanks.

The state-of-the-art in explosive excavation has been significantly advanced in recent years. With the potential for using large quantities of explosives in such applications, a capability to drill large holes is essential if this new tool is to be fully utilized. It was learned in Vietnam, that in certain locations, massive quantities of crushed rock must be produced in order to build and to maintain effective lines of communication. Current capabilities proved inadequate for the needs in this particular situation. As mentioned earlier, the quarrying industry is now using large quantities of bulk explosives to increase production. This same capability is required if the Army is to be prepared for all types of combat situations. In addition to a bulk explosive, rock drilling equipment is required to produce rapidly emplaced, larger, deeper holes for production blasting.

3. Utilities. In the area of utilities construction, an improved capability to install water wells and utility poles is required to enhance base development operations.

B. Drilling Capabilities. In view of the current capabilities of commercial drilling equipment, Army drilling equipment might be considered quite antiquated. Rock drilling equipment includes a hand-held pneumatic percussion drill capable of drilling a 51-mm (2-in)-diameter hole to a depth of 3 m (10 ft), wagon- and crawler-mounted drifters capable of drilling up to 0.1-m (4-in)-diameter holes to a depth of 7.3 m (24 ft), and a well-drill capable of drilling 0.2 m (8-in.)-diameter holes to a depth of 305 m (1000 ft). The only earth drilling equipment available is a skid-mounted earth auger, which can drill holes up to 0.5 m (20 in.) in diameter to a depth of only 2.7 m (9 ft).[1]

C. Proposed Procurement. An effort is being made to gain approval for procurement of a commercial-type drilling machine for military use. A Requirement Operational Capability (ROC) is being evaluated and, if it is approved, evaluation of existing commercial equipment will begin. The specifications included in the ROC call for a drilling machine capable of drilling a 0.9-m (3-ft)-diameter hole to a depth of 18.3 m (60 ft) in a maximum of 2 h. The material to be excavated includes soil and very soft rock. The machine must also have a capability for underreaming the bottom of the hole to a diameter of 1.8 m (6 ft). If this proposed capability is approved and a suitable drilling machine is procured, a major step toward satisfying the requirements described above will have been taken. Yet to be met is the requirement to drill larger holes more quickly in medium and hard rock.

III. DEVELOPMENT OF THE SUBTERRENE CONCEPT

A. History. The subterrene (rock melting) concept was first generated over a decade ago at LASL. Unfortunately, insufficient interest in its development prevented funding for immediate research. Thus, the concept lay essentially dormant until recent years. In the early 1970's, LASL revived the concept and was able to obtain development support funds from the National Science Foundation (NSF).

The initial basis for this support was the desire to develop an improved tunnelling capability. Development research began with tunnelling as its initial goal. Midway through this first-year effort, the emphasis was changed by the sponsor. LASL was asked to concentrate its efforts on developing a subterrene capable of drilling deeply into rock. In deep holes where rock temperatures rise to a significant level, conventional drilling techniques encounter serious problems. The subterrene was viewed as a device the effectiveness of which might be enhanced by these rising temperatures. When NSF was unable to continue its support of the subterrene development during the following year, the Atomic Energy Commission (AEC) provided for its continued development. The goal of the AEC gave another new direction for the developers. It called for the development of a working subterrene capable of drilling nonlinear exploration holes through granular materials. LASL is working toward this goal and plans to begin on-site field testing soon.[2]

B. Concept and Devices. The subterrene concept is based on the fact that most rocks melt at about 1200°C (2200°F), and that materials are available that can be heated to this temperature without nearing their melting points.[3] Thus, a penetrator manufactured from some such material, heated to a temperature in excess of 1200°C, and pressed against rock by an external load should melt a path through the rock.

The initial device developed to test the concept consists of an electric heating element encased in a bullet-shaped metal penetrator (see Fig. 1). A series of hydraulic jacks provide a controlled loading to push the penetrator forward as the rock melts. The molten rock is

Fig. 1. Prototype of consolidating-penetrator subterrene.

forced into rock fractures, pores in the rock, and back alongside the penetrator as the penetrator advances. When properly adjusted for temperature and advance rate, this subterrene can leave a relatively impervious glass-lined hole. Although rock drilling was the primary goal, the glass lining prompted the testing of the device in granular soil in which hole casing is normally a necessity in conventional drilling. Tests performed in these soils showed that the glass lining was again formed and served as an effective casing.

Problems encountered in penetrating dense, unfractured rock, coupled with a desire to increase hole sizes led to the search for a technique for evaluating at least part of the molten rock. Whereas the original device consolidated the melted materials, the new device would be required to extrude the material. Thus, the subterrene technique was expanded to include two types of operation, consolidation and extrusion.

The extrusion penetrator still leaves a glass-lined drill hole; however, the bulk of the melted material is removed to the surface. The technique used for this removal includes the use of forced gaseous coolant circulating through the device. As the coolant returns to the surface, it cools the melt and carries it out of the hole through the center of the penetrator stem. The rock-melt debris can be extruded as glass rods, glass pellets, or rock wool. The system for removing the debris is not unlike that used in conventional rotary rock drills.[4]

C. Support Equipment. The total system for the current subterrene devices is somewhat complex. Both extrusion and consolidation devices require precision monitoring and control equipment to ensure maintenance of optimum penetrator temperatures and advance rates. Both also require an electrical power source, a load application structure, and a supply of compressed coolant to cool the penetrator and in extrusion to cool and remove debris.

D. Evaluations. The subterrene prototypes have been extensively evaluated in both laboratory and field environments. They have successfully drilled small-diameter holes in various types of soils and rock, including tuff, granite, and basalt (Fig. 2). Use in an actual field application has been accomplished, and another field application

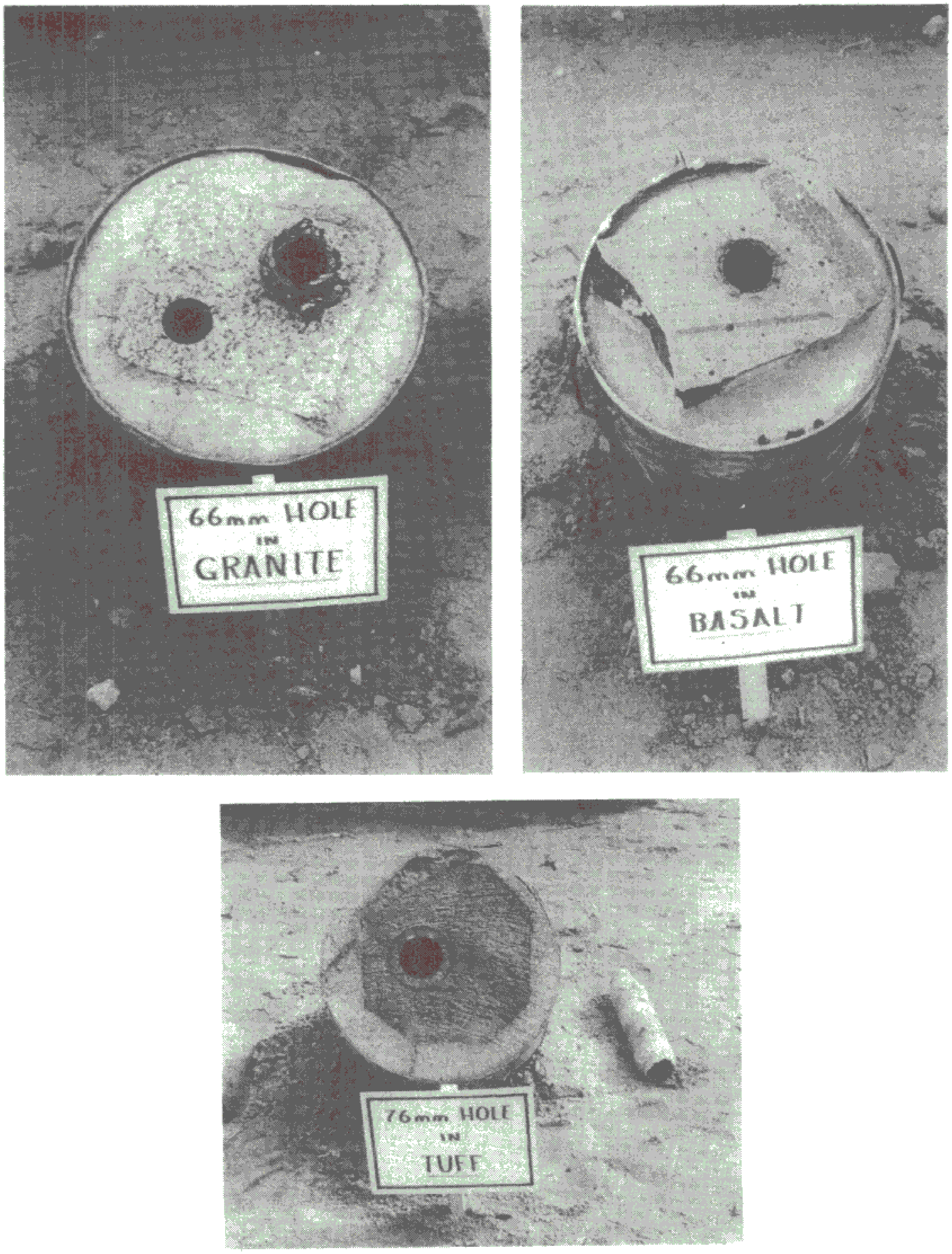


Fig. 2. Holes drilled in rock samples by consolidating-penetrator subterrene.

is planned for the near future.

E. Future Plans. LASL developers envision expansion of the subterrene's capability to include the drilling of much larger holes. It is expected that such a device will consist of a series of small penetrators mounted together in a circular configuration (or some other shape if desired). On very large holes, such as tunnels, the subterrene would probably be used to excavate and to line the extremities of the hole; some other method, possibly conventional, would be used to fracture and remove the core material. Another extension being considered is the development of a device that will leave intact a glass-coated center core removable for exploratory examination. The ultimate subterrene is a tunnelling machine with a self-contained nuclear power source to support its operation.[5,6]

IV. CAPABILITIES AND LIMITATIONS OF THE SUBTERRENE FOR DRILLING APPLICATIONS

A. Penetration Rate. The penetration rate of the subterrene varies considerably with the mode of operation (i.e., consolidation or extrusion) and the medium being penetrated. These rates can be predicted with reasonable accuracy based on the medium properties, penetrator design, and melting power (melting power is that portion of the total power input applied to melting the rock). Essentially, the penetration rate is proportional to the melting power with the proportionality constant being dependent upon the media properties and penetrator design.[7] The 90-mm (3.5-in) consolidation prototype has demonstrated penetration rates ranging from 1.4 m/h (4.5 ft/h) in hard soil to 6.1 m/h (20 ft/h) in soft soil. The extrusion prototype has drilled 30-mm (1.2-in.)-diameter holes through rock at rates of 0.6 m/h (2 ft/h) in hard material and 1.5 m/h (5 ft/h) in soft rock.[2] Although these rates appear to be quite low, it must be remembered that refinements of the subterrene are continuing, and one of the foremost goals is to improve these rates significantly. Analysis (by developers) of what might be considered a typical military requirement, drilling of 0.6-m (2-ft)-diameter shafts in hard rock or soil, has led to the conclusion that equipment with the following specifications can be developed:[8]

Hole Diameter	0.6 m (2 ft)
Hole Depth	20 m (100 ft)
Penetration Rate	1.0 mm/s (10 ft/h)
Power	200 kW
Coolant Type	Air
Hydraulic Thrust Force	20 to 50 x 10^3 lb

B. Support Requirements. The presently working subterrene prototype is supported by two major mobile items of equipment. The first, a flat-bed semitrailer, consists of a derrick-type mast mounted on the rear, a power supply for the hydraulic jacking system, and a rectifier to convert an external AC power supply to DC for heating the penetrator.[8] The second item of equipment is a control van semitrailer, which houses the monitoring and control equipment. The

compressed coolant supply, like the electrical power, is furnished by an outside source. It is anticipated that the design of a single self-contained unit could be accomplished if such a design is desired. A single power source mounted on the semitrailer could be tailored to meet the electrical, compressed coolant, and hydraulic needs of the system. A compact control unit could also be mounted on the same semitrailer.

Operation of the subterrene prototypes in remote locations requires both electrical generation equipment and an air compressor. A 10-kW gasoline engine generator is adequate to meet electrical needs, and a 105 ft^3/min compressor (actual use = 35 ft^3/min) will provide the coolant flow to support the cooling and debris evacuation functions. The general rule-of-thumb used in estimating power requirements for future larger-scale equipment is that the power needed increases as the square of the penetrator diameter. The fuel consumption of the generator and compressor is approximately 4 gal/h during subterrene operation. Theoretically, the subterrene, after set-up has been accomplished, can be operated by one person; however, it is expected that additional personnel will be required for set-up and maintenance and repair operations.

C. Costs. The cost of operating the subterrene is quite high when compared with conventional drilling. Early cost analyses for the consolidating penetrator revealed that total operating costs ranged from \$8.04/m (\$2.45/ft) to \$26.74/m (\$8.15/ft) depending upon the type of penetrator used and the temperature of operation. The analysis addressed penetration of unconsolidated material. These figures are based upon the cost of construction of prototype one-of-a-kind penetrators and probably represent the upper limits for this type of operation.[9] Despite this fact, the lowest cost operation does not favorably compare with a conventional percussion drill operation costing on the order of \$3.30/m (\$1.00/ft) in hard limestone. In cases in which granular materials are encountered, this variance may be significantly reduced if casing of the conventional hole is required, since the subterrene produces its own glass-like casing. Efforts are continuing to

reduce subterrene operating costs to a point at which the costs become competitive with those of conventional equipment. At present, however, only in very special applications involving serious drilling problems can the subterrene hope to compete on an economic basis.

D. Special Advantages. The subterrene offers several special advantages over conventional drilling equipment in certain cases. Although some of these have been mentioned earlier, it is appropriate to review them. The subterrene lends itself to precision drilling. Since the rock or soil material is melted during penetration, the concern for misalignment of the penetrator upon encountering perturbations in the medium is minimized. Such is not the case for conventional drilling. Conventional drills are easily pushed off-course by hard rocks in soil or fault planes in rock. Thus, the subterrene offers a major advantage when hole alignment is a critical issue.

Casing of drill holes becomes a serious problem in conventional drilling. It is both time-consuming and often only marginally successful. The subterrene creates a natural casing in the form of the glass lining produced during penetration.

Tests indicate that the quality, thickness, and continuity can be influenced by the operator to meet the needs of each particular situation. The life of a conventional rock bit is relatively short when the drilling is in hard rock. The need to change these bits regularly reduces the effectiveness of the drilling operation, especially when very deep holes are to be drilled. The subterrene penetrator life is not nearly so restricted and far exceeds that of the rock bit. This penetrator life enhances the subterrene's capability for providing continuous operation for an extended period -- especially true when very deep drilling is involved.

Whereas the rotary drill begins to encounter severe problems at depths at which rock temperatures become very high, the subterrene takes full advantage of this increased temperature and is able to increase productivity.

The subterrene demonstrates environmental advantages over conventional equipment when rock is being drilled; for example, the loud

noise and dust produced by rotary and percussion drills do not exist at a subterrene site. The noise level is limited to that caused by the operation of a generator and a compressor, and these may be remotely located to reduce their effects further. No dust is produced by the subterrene; thus, this nuisance and health hazard normally encountered in rock drilling is eliminated.

V. EVALUATION OF THE SUBTERRENE FOR MILITARY DRILLING APPLICATIONS

In evaluating the suitability of the subterrene for military drilling applications, a typical combat support mission will be used. An analysis of the potential for using the subterrene to support this mission should provide insight into the subterrene's applicability.

The emplacement of an explosively produced crater to close a barrier system would be an extremely high priority combat support mission. Such an obstacle, to be effective, must be on the order of 30 m (100 ft) wide. To produce a crater of this size, the explosive charge would probably range between 4,500 and 9,000 kg (5 and 10 tons). To optimize placement, a vertical shaft with a diameter of 0.5 to 1 m (1.6 to 3.4 ft) to a depth of 6 to 12 m (20 to 40 ft) must be drilled. Since closure of a barrier is normally done in the face of advancing enemy forces, the ability to drill the emplacement hole and place the explosives within a very short time (3 to 4 h at most) must exist. Can the subterrene effectively support such a task?

Although developers predict that a penetrator system could be developed to drill a hole with a diameter on the order of that required, such a design is still highly theoretical. A multiple penetrator head system would be required to attain such hole sizes, and, although a subterrene of this type can probably be developed, development costs will be high and there is no assurance of success.

If the required diameters could be provided, it is anticipated that other requirements might still not be met. Hole depths of 12 m (40 ft) should present no serious problem; however, penetration rates as high as those required to meet the time limits seem impossible with the present, and even projected, state-of-the-art for the subterrene. Penetration rates of 3 to 6 m/h (10 to 20 ft/h) are needed to produce an emplacement hole quickly. Such rates can be achieved with current drills and augers in soil. To create a similar capability for rock presents a most difficult challenge.

Assuming all of the above problems could be overcome, two other difficulties would still exist for the combat engineer. To expedite crater production, explosives must be placed into the drill hole as soon

as drilling is completed. This would be extremely dangerous and possibly prohibitive with the subterrene since the material surrounding the hole will remain quite hot for some time. In addition, the maneuverability of a large semitrailer-mounted drill rig will greatly reduce the rapidity with which the site can be reached and the subterrene placed in operation. In some cases, it would be necessary to select a less-than-optimum location due to the inability of the unit to reach the best emplacement location. The degree to which the drilling unit can be decreased in size is extremely limited when one considers the data presented in paragraph IV A for a 0.6-m (2-ft) hole.

The subterrene shows promise for improving the overall drilling capability of the U. S. In its present configurations it is best-suited for special applications in which particular problems are encountered that cannot easily be solved by conventional methods. The most promising future uses appear to be in the areas of deep drilling for geothermal energy recovery and rapid drilling of tunnels through hard rock. The unique capabilities of the subterrene may even be required for special military engineering tasks; however, it is expected that the number of such cases would be limited.

VI. CONCLUSIONS

The subterrene, in its present configuration and with its projected capabilities, does not meet a significant number of the drilling requirements of the Army. The subterrene developers are continuing their attempts to improve its performance. The short-term development goals for the subterrene do not promise to improve significantly its applicability to military requirements.

At some later date, if significant improvements in the subterrene have been achieved, the above conclusion should be reevaluated.

REFERENCES

1. Joseph Briggs, Military Engineering Applications of Commercial Explosives: An Introduction, U. S. Army Engineer Waterways Experiment Station Explosive Excavation Research Laboratory, Livermore, CA, Report TR-E-73-2 (1973).

2. Private communication Dr. C. A. Bangston, LASL (1 July 1974).

3. The Los Alamos Rock-Melting Subterrene: How It Works, Los Alamos Scientific Laboratory, Los Alamos, NM, (undated).

4. J. W. Neudecker, A. J. Giger and P. E. Armstrong, Design and Development of Prototype Universal Extruding Subterrene Penetrators, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-5205-MS (1973).

5. R. J. Hanold, Large Subterrene Rock-Melting Tunnel Excavation Systems: A Preliminary Study, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA 5210-MS (1973).

6. E. S. Robinson, R. M. Potter, B. B. McInteor, J. C. Rowley, D. E. Armstrong, R. L. Mills, and M. C. Smith, A Preliminary Study of the Nuclear Subterrene, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-4547 (1971).

7. R. G. Gido, Subterrene Penetration Rate: Melting Power Relationship, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-5204-MS (1973).

8. Prospectus of Subterrene Devices of Potential Interest to U. S. Army Corps of Engineers, Los Alamos Scientific Laboratory, Los Alamos, NM, (March 1974).

9. Private communication, D. L. Sims, LASL (20 April 1973).

BIBLIOGRAPHY

Armstrong, D. E., J. S. Coleman, B. B. McInteer, R. M. Potter, E. S. Robinson, Rock Melting as a Drilling Technique, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-3243 (1962).

Black, D. L., Technical Summary: Basic Understanding of Earth Tunnelling by Melting, Westinghouse Electric Corporation, Pittsburgh, PA, Report WANL-TME-2841, Vol 1 (1973).

Gido, R. G., Description of Field Tests for Rock-Melting Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-5213-MS (1973).

Gido, R. G., Internal Temperature Distribution of a Subterrene Rock-Melting Penetrator, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-5215-MS (1973).

Krupa, M. C., Phenomena Associated with the Process of Rock Melting, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-5208-MS (1973).

Murphy, D. J., and R. G. Gido, Heat Loss Calculations for Small-Diameter Subterrene Penetrators, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-5207-MS (1973).

Neudecker, J. W., Design Description of Melting-Consolidating Prototype Subterrene Penetrators, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-5215-MS (1973).

Rowley, J. C., The Subterrene Program, Los Alamos Scientific Laboratory, Los Alamos, NM, Mini-Review 73-1 (1973).

Sims, D. L., Identification of Potential Applications for Rock-Melting Subterrenes, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-5206-MS (1973).

Williams, R. E., Development and Construction of a Modularized Mobile Rock-Melting Subterrene Demonstration Unit, Los Alamos Scientific Laboratory, Los Alamos, NM, Report LA-5209-MS (1973).

DISTRIBUTION

Roger E. Batzel, L-1	
Earth Sciences Division, L-41	
D-Division, L-92	
TID File, LLL, L-3	5
Dr. J. C. Rowley Los Alamos Scientific Laboratory P. O. Box 1663 Los Alamos, NM 87544	
HQDA (DAEN-ZS) WASH DC 20314	
HQDA (DAEN-RDM/LTC Hughes) WASH DC 20314	
HQDA (DAEN-CWE-G/W. McIntosh) WASH DC 20314	
US Army Engineer School ATTN: Technical Library ATSE-CTD-MS Ft. Belvoir, VA 22060	2
USAE Waterways Experiment Station ATTN: Library P. O. Box 631 Vicksburg, MS 39180	
USAE Waterways Experiment Station ATTN: S&PL	
USAE Waterways Experiment Station ATTN: WEL	
Defense Document Center ATTN: Scientific & Technical Information Cameron Station Alexandria, VA 22314	12
Explosive Excavation Research Laboratory L-396	21

9045

SELECTED TOP SECRET UNDERGROUND INSTALLATIONS THAT THREATEN OUR LIBERTY

Somewhere between 75 and 100 secret underground facilities have been built, many are underground small-cities. A number of these bases have been described to me by witnesses including NORAD, Dulce, Coos Bay, and Dreamland.

Format is as follows:
Site name, site location, group/groups in control, size, activity

ARIZONA

- **Fort Huachuca- reported saucer base**
- **Santa Catalina Mountains -reported saucer base**

ARKANSAS

- **in the vicinity of Hardy and Cherokee Village -reported saucer base**

CALIFORNIA

- **29 Palms Marine Base -reported saucer base southwest of Ludlow. This is a U.S. alien research/ diagnostic facility and UFO base. Identified on military map as airspace area R-2501N.**
- **Deep Springs, CA- reported saucer base**
- **Fort Irwin, CA- reported saucer base**
- **Edwards Air Force Base, in the area where Diamond Cr. & the so. fork of the Yuba meet, underground UFO base.**
- **George Air Force Base, CA - reported saucer base**
- **Helendale, Lockhead Underground Facility, technology for secret projects.**
- **Los Angeles, On Hwy 14 towards Edwards A.F.B. after Palmdale, one turns off and after taking several streets to 170th street, north on 170th St. to the Rosamond-170th intersection, the second and lower and better maintained dirt road will take you west, and if you take a right going north at the power lines and up to the hilltop you will see the top of an underground NORTHOP facility. Technology for the elite's secret projects.**
- **Kern River, CA the hollowed out mountain next to the hydroelectric facility at the Kern River Project near Bakersfield- reported saucer base**
- **Norton Air Force Base- reported saucer base**
- **Near Palmdale (if one takes Palmdale Blvd. til 240th St. and goes to Ave R-8. One the eastern limit of Ave. R-8 is McDonnell-Douglas's facility called the Llano Facility. One can see it better from the Three Sisters Hills to the south of the facility.**
- **Santa Rosa, FEMA, Regional center for west coast, what FEMA is doing is mostly kept secret**
- **Tecachapi Ranch- reported saucer base**

COLORADO

- **Alamosa- reported saucer base**
- **Colorado Springs, NORAD --Canada & U.S., & FEMA, hundreds of people on staff, contains at least 4.5 acres of underground caverns and 15 underground steel buildings. This complex tracks thousands of satellites, missiles, submarines, and UFOs. NORAD also controls many Monarch slaves who have ALEX, JANUS, ALEXUS endtime callback programming.**
- **Fort Collins- reported saucer base**
- **Grand Mesa- reported saucer base**

FLORIDA

- **Massive base- reported saucer base**
- **Eglin AFB- reported saucer base**

GEORGIA

- **Thomasville, FEMA, regional center, activity unknown**

MARYLAND

◘ Fort Meade, below Ft. Meade, National Security Agency, 10 acres of the most sophisticated supercomputers that can be built, very large complex, massive surveillance of all the world's communications, including all transmissions in the U.S. and in the world of telephones, telegraph, telex, fax, radio, TV and microwave transmissions.

◘ Olney, actually the facility is between Olney and Laytonsville, on Riggs Rd. off of Rt. 108. Another underground facility may also exist in the area, FEMA & possibly NSA, the facility may be 10 levels deep, purpose unknown.

MASSACHUSETTS

◘ Maynard, FEMA, regional center, size and activity unknown

MICHIGAN

◘ Battle Creek, FEMA, regional center, activity secret

MISSOURI

◘ 12 miles south of Lebanon, near the newly created town of Twin Bridges- reported saucer base

◘ in the Bat/Dry/Dead Man/ Howell cluster of caves- reported saucer base

NEVADA

◘ Blue Diamond -reported saucer base

◘ Groom Lake, also known as Dreamland, Area 51, The Area, the Spot, Red Square, Sally Corrodor, Watertown Strip. Run by the NWO along with demonic beings, the CIA is there and Wackenhut Security. Two large underground facilities close to but separate from Groom Lake but controlled by the demonic beings are Papoose Range and Cockeyed Ridge (S-4) underground bases. Purpose is the testing of various UFOs and other secret aircraft like the Aurora and Stealth. Also biological work is done, including the manufacture of small greys. Many levels have been built at these three complexes, and a 7 mile long run way has been built over Groom Lake, a dry lake.

◘ Quartzite Mountain SE of Tonopah- reported saucer base

◘ Tonopah, Airforce, CIA? & ??, deals with secret aircraft

NEW JERSEY

◘ Picatinny Arsenal- reported saucer base

NEW MEXICO

◘ Angel Peak- reported saucer base

◘ Carlsbad Cavern area (now destroyed) -reported saucer base

◘ Dulce, N.M.--South of Dulce,in the area of the Jicarilla Indian Reservation, another facility is east of the Dulce facility a number of miles. This is run directly by Illuminati w/ Army and Airforce help, CIA also conduct experiments at the center; the size of the installation is hugh requiring small shuttle trains and has seven levels according to witnesses. Serves as a UFO base, biological experiments, production center for small-grey drones. Wackenhut provides some of the security on the ground.

◘ Manzano Mtn, near Albuquerque, known as the Kirtland Munitions Storage Complex, Airforce, 3,000-acre base within the Kirtland AFB/Sandia National Labs complex, guarded by 4 lethal rings of fences, use unknown, suspected UFO base. A new 285,000-sq. ft. bunker is being built near Manzano Base.

◘ Pie Town, in area near Pie Town, UFO Base.

◘ Sandia Mountains NE of Albuquerque -reported saucer base

◘ to the north of Taos Pueblo - reported saucer base

NEW YORK

◘ Plattsburgh (near Canada and St. Albans) AFB- reported saucer base

OKLAHOMA

◘ Ada, underground saucer base

DUM (Deep Underground Military Bases)

SELECTED TOP SECRET UNDERGROUND INSTALLATIONS THAT THREATEN OUR LIBERTY

140 secret underground facilities have been built, many are underground small-cities. A number of these bases have been described to me by witnesses including NORAD, Dulce, Coos Bay, and Dreamland.

What I am describing is a series of large underground facilities which are connected with tunnels. The tunnels carry extremely fast trains. Train terminals are up to 1 million sq. ft. in area, with multiple levels. Underground facilites contain computer centers, genetic experimentation, mind-control research, housing for several nationalities of humans and several varieties of aliens. The corporations which assist the NWO are able to quietly interlink their facilities via the tunnel system too, as well as disperse some of their workers into the world above ground.

There are approx. 50 ways tunnels and underground facilities are dug, which include high pressure continuous water jet, low pressure percussive water jet, high freq. electrical drill, turbine drills, pellet drills, spark drills, explosives, hydraulic rock hammers, lasers, electron beam guns, forced flames, etc. These various tunnelling methods can be broken down in Mechanical (such as a water canon), Thermal (such as a high velocity flame, laser, atomic fusion, etc), and Chemical (such as a dissolver). The beautiful thing about nuclear subterrenes (rhymes with submarine) is that they don't leave any debris to despose of. These nuclear subterrenes are building tunnels 40' in diameter, and as these machines work the rock is melted into a hard, glassy tunnel lining.

Air-intake shafts bring fresh air to the tunnels and underground facilites. Underground facilities have fuel storage units, air-conditioning, water reservoirs, dining, medical, sleeping and storage units.

Many of the underground sites are close to railroads and have entrances that trucks can drive into. Some of the entrances for trucks are protected by holograms that look like the side of a mountain, but allow vehicles if one just drives through them. The other style of hidden entrances are buildings where trucks drive in and are lowered via access shafts down into the underground areas.

Security for some (such as Groom Lake) of the facilites is maintained by Wackenhut. Penetration tests on facilities are carried out by a special unit called OP-06-D which are HQed at Offutt AFB, NE.

Format is as follows:
Site name, site location (warning: longitudes & latitudes were quick off of the head estimates), group/groups in control, size, activity

ARIZONA

◘ 1. Fort Huachuca. 31°50' N 110° 19'48" W, saucer base below, intelligence training above, mind-control incl. too.

◘ 2. Gates Pass Base

◘ 3. Gila Mountain Area, south of Interstate 8 and approx. 30 east of Yuma, AZ. 29° N 116°W. DUM base.

◘ 4. Grand Wash Cliffs, on western edge of the cliffs at the head of Grapevine Wash. Must

be reach via hwy 93 and then unpaved roads. DUM base.

◘ 5. Green Valley

◘ 6. Hualapai Mountains, east side of the mountain range, about 35 mi. SE of Kingman, AZ

◘ 7. Rincon Mtn., north side of Rincon Mtn

◘ 8. Mt. Lemmon

◘ 9. Page

◘ 10. Safford, near Safford

◘ 11. Santa Catalina Mountains - base

ARKANSAS

◘ 12. In the vicinity of Hardy and Cherokee Village. 36° 19' N 91°29' W. Installation purpose not known.

◘ 13. Pine Bluff, Ark. area. 34° 13.4' N 92°01.0'W to 34°30' N 92° 30'W. saucer base.

CALIFORNIA

◘ 14. 29 Palms Marine Base, Identified on military map as airspace area R-2501N. Saucer base southeast of Ludlow. This is a U.S. alien research/ diagnostic facility and UFO base.

◘ 15. China Lake, mind control and weapons research

◘ 16. Darwin, CA, 4 miles dues west of Darwin

◘ 17. Deep Springs, CA, 37°22' N 117° 59.3' W. saucer base

◘ 18. Fort Irwin, CA, 35°20'N 116°8' W. saucer base

◘ 19. Edwards Air Force Base, in the area where Diamond Cr. & the so. fork of the Yuba meet, there are 3 underground UFO bases. 34°8' N 117° 48' W

◘ 20. George Air Force Base, CA - saucer base

◘ 21. Helendale, Lockhead Underground Facility, 34°44.7' N 117° 18.5' W. Technology for secret projects. There are 3 saucer bases here.

◘ 22. Los Angeles, On Hwy 14 towards Edwards A.F.B. after Palmdale, one turns off and after taking several streets to 170th street, north on 170th St. to the Rosamond-170th intersection, the second and lower and better maintained dirt road will take you west, and if you take a right going north at the power lines and up to the hilltop you will see the top of an underground NORTHOP facility. Technology for the elite's secret projects. This area was very active in the 1970s. Northrop's facility is near the Tehachapi Mtns. It has been reported to go down 42 levels. It is heavily involved with electronics and hi-tech aerospace research.

◘ 23. Mt. Shasta

◘ 24. Kern River, CA the hollowed out mountain next to the hydroelectric facility at the Kern River Project near Bakersfield- reported saucer base

◘ 25. Napa Valley- located at Oakville Grade north of Napa, CA. Tunnels also connect the wineries north of Napa, used for white slavery and mind-control. Has a saucer base.

◘ 26. Norton Air Force Base- saucer base

◘ 27. Quincy, CA, 39° 56.2' N 120° 56.5' W. saucer base

◘ 28. Near Palmdale (if one takes Palmdale Blvd. til 240th St. and goes to Ave R-8. One the eastern limit of Ave. R-8 is McDonnell-Douglas's facility called the Llano Facility. One can see it better from the Three Sisters Hills to the south of the facility. Strange shaped disks raise out of the ground on pylons. These attached disks glow and change color. It is involved in hi-tech aerospace technology.

■ 29. Presidio, CA - A FEMA/DOD site for Region IX's regional office
■ 30. San Bernardino, CO, 34° 50' N to 34° 16' N
■ 31. Santa Barbara County - placed in the thick diatomite strata
■ 32. Santa Rosa, 38° 26.4' N 122° 42.9' W, FEMA, Regional center for west coast, what FEMA is doing is mostly kept secret. This is listed as a Communications Antenna Field, but is doing much more.
■ 33. Sierra Nevada Mountains, CA - very deep military base
■ 34. Tehachapi Ranch- 4 saucer bases, Tecachapi Canyon has a new underground base which was finished in Sept. '95. This is the "Unholy 6" base of the Orions. 35° 20' 118° 40'
■ 35. Trona, CA, 35° 45.5' N 177°22.6' W --several miles northwest of Trona, directly under Argus Peak. This DUM sits on China Lake's NWC's land, and may have been built in the '60s.

COLORADO

■ 36. Alamosa, 37° 28.1' N 105°52.2' W- reported saucer base
■ 37. Book Cliffs, CO, 39° 40' N 108° 0' W near Rifle, CO -
■ 38. Boulder, CO--The headquarters for EMC, a type of electra-magnetic mind control that is being broadcast to modify the thinking of Americans, and to control slaves.
■ 39. Colorado Springs, NORAD --Canada & U.S., & FEMA, hundreds of people on staff, contains at least 4.5 cubic miles of underground caverns and 45 underground steel buildings. Many underground chambers are as large as 50' x 100 '. This complex tracks thousands of satellites, missiles, submarines, and UFOs. NORAD also controls many Monarch slaves who have ALEX, JANUS, ALEXUS endtime callback programming. NORAD installation has 1278 miles of road underground.
■ 40. Fort Collins- base for Gray aliens
■ 41. Grand Mesa- Orion saucer base
■ 42. Montrore Co.--north of Paradox, in Paradox Valley. The site in Paradox Valley can be reached via Hwy. 90 via Nucla.

CONNECTICUT

■ 43. North west Connecticut

FLORIDA

■ 44. Massive base- reported saucer base
■ 45. Eglin AFB, 30° 40' N 86° 50' W- Orion saucer base since 1978

GEORGIA

■ 46. Atlanta, GA --FEMA regional center, which is appropriately placed since Atlanta is to become a capital within the NWO redrawing of bounderies. Atlanta is believed to have several underground installations in its area, one to the north at Kennesaw Mtn., Marietta, GA connected to Dobbins AFB and one to the south of Atlanta at Forest Park.
■ 47. Thomasville, 30° 50.2' N 83°58.9' W, FEMA, regional center, they train groups in Search and Destroy missions for when Martial Law is imposed. This is SW Georgia in area of tunnels.

IDAHO

◘ 48. Lower Goose Lake area in the general area of Oakley, ID.--Wackenhut of the Illuminati run a "model prison" for the NWO. The worst of the federal prisoners are placed in this underground prison which has 7,100 cells which are filled with about 2,700 federal inmates. A track runs through the middle of the eerie underground facility. Food and showers are on the tracks, and the men are allowed showers once a week. The minimum of lighting is used and the men are beaten senseless if they talk at all. It sits 500' underground.

◘ 49. South central Idaho--under the Snake River lava flows between Twin Falls and Idaho Falls.

INDIANA

◘ 50. Bedford & Lawrence Co. area--continued activity in large old mines indicates a possible government use of the large old quarries.

KANSAS

◘ 51. Atchison, KS--the DIPEF underground facility, which the govt. would run in an emergency. AT & T maintains an underground facility at Fairview, KS.

◘ 52. Kinsley--an underground UFO base

MARYLAND

◘ 53. Camp David--just north of the camp is an underground facility important to the intelligence agencies.

◘ 54. below Ft. Meade, of the National Security Agency, 10 acres of the most sophisticated supercomputers that can be built, very large complex, massive surveillance of all the world's communications, including all transmissions in the U.S. & world of telephones, telegraph, telex, fax, radio, TV and microwave transmissions.

◘ 55. Olney, actually the facility is between Olney and Laytonsville, on Riggs Rd. off of Rt. 108. Another underground facility may also exist in the area, FEMA & possibly NSA, the facility may be 10 levels deep, purpose unknown.

◘ 56. Suitland, MD- Classified archives of U.S. Govt. stored here in underground levels. Vaults have extensive amounts of documents which are not indexed. Restricted access with a coded security card. High level intelligence groups operate in the area also.

MASSACHUSETTS

◘ 57. Maynard, 42° 26.0' N 71°27.0' W FEMA, regional center, Wackenhut is here too.

MICHIGAN

◘ 58. Battle Creek, 42° 19.3' N 85° 10.9' W FEMA, regional center, activity secret (not validated)

◘ 59. Gwinn, MI, 46° 16.8'N 87° 26.5' W, near Gwinn is a large underground base which is a key base for sending signals. An AFB is also nearby. Under Lake Superior is an alien base with roads 5,000' deep.

MISSOURI

◘ 60. 12 miles south of Lebanon, 36° 02.8' N 115° 24.3' W, near the newly created town of Twin Bridges- reported saucer base

◘ 61. In the Bat/Dry/Dead Man/ Howell cluster of caves- reported saucer base

◘ 62. St. Francis Mountains, MO (between St. Louis & New Madrid)

NEBRASKA

◘ 63. North-central Nebraska

◘ 64. Red Willow Co. near McCook, NE

NEVADA

◘ 65. Blue Diamond, 36° 02.8'N 115°24.3' W -reported saucer base

◘ 66-68. Groom Lake, also known as Dreamland, Area 51, The Area, the Spot, Red Square, Sally Corrodor, Watertown Strip. 115° 50'N 37°20' W. Run by the NWO along with demonic beings, the CIA is there and Wackenhut Security. Two large underground facilities close to but separate from Groom Lake but controlled by the demonic beings are Papoose Range and Cockeyed Ridge (S-4) underground bases. Purpose is the testing of various UFOs and other secret aircraft like the Aurora and Stealth. Also biological work is done, including the biological raising of small greys. Many levels have been built at these three complexes, and a 7 mile long run way (which is actually 39 miles) has been built over Groom Lake, a dry lake. There is an S-2, an S-4, an S-6, and an S-66 underground installations. S-66 is the most secret and it has 29 levels and is 11, 300' deep.

◘ 69. Quartzite Mountain SE of Tonopah, 37° 31'N 116° 20' W- reported saucer base

◘ 70. Tonopah, Airforce, CIA? & ??, deals with secret aircraft

NEW HAMPSHIRE

◘ 71-73. There may be as many as three underground installations in New Hampshire's hills (according to reports).

NEW JERSEY

◘ 74. Picatinny Arsenal, 40° 38'N 74° 32' W- saucer base, 1/4 cubic mile large and very deep underground.

NEW MEXICO

The state of New Mexico and Colorado have been used for the construction of a series of underground bases. (All the rest of the states have too.) The Primary Underground facilites in New Mexico consist of:

- 3 enormous underground bases in the Dulce, NM area (an area I spent several days investigating in 1993)
- the White Sands--Alamogordo Area which has 3 underground bases
- Datil and Pie Town which have two more underground bases. (Carlsbad Cavern which had underground activity, which is reported discontinued, and another base to east of Carlsbad.)
- the Los Alamos area underground facility
- the Taos area underground facility

The New Mexico area has basically four underground system out. One goes to the 4-corners area and then to Groom Lake (Area 51). One goes north toward Delta, CO and

Colorado Springs. The Taos facilites goes north approximately along Interstate 25 and eventually ties in NORAD. The southern bases connect to Texas and Mexico.

The Los Alamos facility dates at least back to 1940. One can only imagine what has been built with 1/2 century of labor on this underground system.

Visitors to the deeper levels report humans kept in glass cylinders, plus many other strange things. I have had the opportunity to debrief some people who have been in the lower reaches of some of these facilities.

There are special badges, special uniforms, tube elevators etc. which for lack of time I will not describe.

- 77. Angel Peak- reported saucer base
- Carlsbad Cavern area (now destroyed), 32° 25.0'N 104° 14.0'W -old relics of saucer base left
- 78-80. Dulce, N.M., 36° 56.0'N 106°59.8'W,--South of Dulce,in the area of the Jicarilla Indian Reservation, another facility is east of the Dulce facility a number of miles. This is run directly by Illuminati w/ Army and Airforce help, CIA also conduct experiments at the center; the size of the installation is hugh requiring small shuttle trains and has seven levels according to witnesses. Serves as a UFO base, biological experiments, production center for small-grey drones. Wackenhut provides some of the security on the ground.
- 81. Kirtland AFB, NM, Sandia National Lab
- 82. Manzano Mtn, near Albuquerque, known as the Kirtland Munitions Storage Complex, Airforce, 3,000-acre base within the Kirtland AFB/Sandia National Labs complex, guarded by 4 lethal rings of fences, use unknown, suspected UFO base. A new 285,000-sq. ft. bunker is being built near Manzano Base.
- 83. Pie Town, 34°17.9'N 108°08.7'W, in area near Pie Town, UFO Base.
- 84. Sandia Mountains NE of Albuquerque -reported saucer base
- to the north of Taos Pueblo - reported saucer base
- 85. White Sands, 32°22.8'N 106°28.8'W, major hub for research, tied in with Dulce and NORAD

NEW YORK

- Adirondack Mountains (near Elizabethtown)
- New York Metro area
- Plattsburgh (near Canada and St. Albans) AFB, 49°40'N 73°33 W- two saucer bases in this area.

OKLAHOMA

- 86. Ada, 34°46.4' N 96°40.7' W, underground saucer base, this base does human cloning, and it is FEMA's most sensitive base.
- 87. Ashland Naval Ammunition Depot, 34°45.9'N 96° 04.3'W,- reported saucer base

OREGON

- 88. Bull Run, north side of Bull Run Resevoir area near Mt. Hood, and very close to Larch Mtn. and south of Benson St. Park of the Columbia Gorge.
- 89. Coos Bay area has had three separate but coordinating underground facilities built for UFOs. The facility farthest east, about 20 miles inland in the wilderness near Hwy 42, has been shut down. It is now an old abandoned facility well camouflaged. The coast facility is

probably still operational.

◘ 90. Klamath Falls, OR--since Sept. '95 this has been a base for a number of NWO groups incl. the Air National Guard, FEMA, CIA, FBI, Spetznaz, and MOSAP training base. An underground concentration camp exists here.

PENNSLYVANNIA

◘ 91. Blue Ridge Summit, near Ft. Ritchie, known as "Raven Rock" or "Site R", Army, major electronic nerve center, 650 ft. below surface with about 350 staff and over a 716 acre area. possibly connected via tunnel to Camp David.

TEXAS

◘ 92. Ft. Hood, TX, 31° 15'N 97° 48' W, home of some Delta Mind-Controlled soldiers and a reported saucer base.

◘ 93. Denton, TX, 33° 13.2'N 97° 08.2'W - FEMA, regional center, activity secret

◘ 94. Red River Arsenal, TX- reported saucer base

VIRGINIA

◘ 95. Bluemont, Mount Weather base, Federal Prepardness Agency & FEMA, small-city underground, top-secret, staff of several hundred, does secret work for FEMA and contains a complete secret government with the various agencies and cabinet-level ranking administrators that keep their positions for several administrations and help run the United States.

◘ 96. Culpepper, 38° 28.5 N 77°59.8'W, about 2 miles east of Culpepper off of Rt. 3, called Mount Pony, Illuminati--Fed. reserve, 140,000 sq. ft., includes a facility for the storage for corpses, monitors all major financial transactions in the U.S. by means of the "Fed Wire", a modern electronic system.

◘ 97. Pentagon, Arlington, VA--

◘ 98. Warrington Training Ctr.--two sites one on Rt. 802 and the other on Bear Wallow Road, on Viewtree Mountain. One is Station A the other Station B. Army & ??, purpose unknown

WASHINGTON

◘ 99. Bothell, 47°45.7'N 122°12.2' W, FEMA, regional center, activity unknown

WASHINGTON, D.C.

◘ 100. WHITE HOUSE, 38°53.5'N 77°02.0'W--The secret NOD underground installation which is connected to the intelligence groups like NSA and the CIA as well as many other nefarious groups lays under the White House with tunnels connecting this NOD installation with the House of the Temple. The Supreme council of the 33° of the Scottish Rite's House of the Temple has a 14' x 25' room in it with 13 chairs where the Illuminati's Grand Druid Council meet. The NOD Deep Underground Installation has numerous levels to it. One eye-witness, went to level 17 (via an elevator) and stated that he believes that deeper levels exist. The NOD installation is involved with psychic (demonic) and satellite control over slaves. This underground complex is to allow the government of the United States to escape a nuclear attack. The enormous complex radiates under Wash. D.C. and connects with many other sites. The tunnel system is used to move some of the mind-control sex slaves. The

walls and ceilings of the tunnels are ceramic tile with fluorescent lighting recessed into the ceilings.

WEST VIRGINIA

◘ 101. Sugar Grove, the Navy's Office of Naval Strategic Intelligence Services monitors U.S. microwave communications. There is also a saucer base here.

◘ 102. White Sulpher Springs, under the Greenbriar Hotel, a mini-city large enough for 800 people equipped with its own crematorium, if there are any other purposes other than listening to U.S. microwave communication it is unknown by this author.

■ **Ashland Naval Ammunition Depot- reported saucer base**

OREGON

■ **Coos Bay area has had three separate but coordinating underground facilities built for UFOs. The facility farthest east, about 20 miles inland in the wilderness near Hwy 42, has been shut down.**

PENNSLYVANNIA

■ **Blue Ridge Summit, near Ft. Ritchie, known as "Raven Rock" or "Site R", Army, major electronic nerve center, 650 ft. below surface with about 350 staff and over a 716 acre area. possibly connected via tunnel to Camp David.**

TEXAS

■ **Ft. Hood, TX, home of some Delta Mind-Controlled soldiers and a reported saucer base.**
■ **Denton, TX - FEMA, regional center, activity secret**
■ **Red River Arsenal, TX- reported saucer base**

VIRGINIA

■ **Bluemont, Mount Weather base, Federal Prepardness Agency & FEMA, small-city underground, top-secret, staff of several hundred, does secret work for FEMA and contains a complete secret government with the various agencies and cabinet-level ranking administrators that keep their positions for several administrations and help run the United States.**

■ **Culpepper, about 2 miles east of Culpepper off of Rt. 3, called Mount Pony, Illuminati--Fed. reserve, 140,000 sq. ft., includes a facility for the storage for corpses, monitors all major financial transactions in the U.S. by means of the "Fed Wire", a modern electronic system.**

■ **Warrington Training Ctr.--two sites one on Rt. 802 and the other on Bear Wallow Road, on Viewtree Mountain. One is Station A the other Station B. Army & ??, purpose unknown**

WASHINGTON

■ **Bothell, FEMA, regional center, activity unknown**

WEST VIRGINIA

■ **Sugar Grove, Navy working for NSA, monitors U.S. microwave communications.**
■ **White Sulpher Springs, under the Greenbriar Hotel, a mini-city large enough for 800 people equipped with its own crematorium, if there are any other purposes other than listening to U.S. microwave communication it is unknown by this author.**

ORGANIZATIONS PRACTICING TRAUMA-BASED MIND CONTROL

Air Force Intelligence
Army Intelligence
Atomic Energy Commission
Boeing
British Intelligence, incl. MI-6, MI-5, & the Tavistock Institute
Bureau of Prisons
Catholic Church
Central Intelligence Agency CIA
CIRVIS
Club 12 & Club 41
Country Music Industry
Defense Intelligence Agency
Department of Justice
Federal Bureau of Investigation
Freemasonry
GEPAN
German Intelligence (Shaback)
GHG
Hollywood
The House of Saud in Saudi Arabia
The Illuminati at all levels are involved in trauma-based mind control as perpetrators & victims.
INS
Ku Klux Klan (different KKK groups)
Los Angeles Dodgers
Mossad
Mormon Church
National Security Agency NSA
National Programs Office
Naval Intelligence (ONI)
OTO
Palo Mayombe
Process Church and its offshoot Chingun etc.
Professional Baseball, such as the L.A. Dodgers
Russian government and intelligence groups
Santaria
Satanic Hubs
Temple of Power (previously

known as Temple of Set)
Umbanda
US Army--esp. the Delta Forces
and the First Earth Battalion
VSAF
Werewolf Order
Some Witchcraft groups besides
Satanism & the Illuminati

Some MAJOR MIND-CONTROL PROGRAMMING SITES with explanations of their programming. (I originally exposed most of these sites in 1993, so it is possible they have made some changes since I originally exposed them. Most of these operated for years, and may still be operating.)

29 Palms, CA

Area 51 (Dreamland, Groom Lake), NV--Area 51 is also known as Dreamland. There are a number of extensive underground facilities in the area. This was one of the first genetic research facilities in the U.S. and perhaps the first major genetic research facility. The people/workers & victims are brought in by airplane and tube shuttle. The worst cases of UFO/alien type of Monarch programming is coming out of Area 51. The eggs from slaves are being harvested and weird genetic creatures are being developed from human eggs which have been genetically mixed with other things.

Boulder, CO--The headquarters for EMC, a type of electra-magnetic mind control that is being broadcast to modify the thinking of Americans, and to control slaves.

China Lake Naval Research Base (Inyokern), CA--This facility had a country store, and hangers, and a hospital (address for the hospital is the code- 232 Naval Air Weapons Station) which all provided sites for programming. This site has been operational since the early 1950s. Large numbers of children (batches of 1,000 or 2,000 or 3,000 children were run through this facility at a time. This facility did much of the original traumas and mind-splitting tortures that created the MPD. Other facilities then specialized in further programming that was then layered in on top of the original China Lake programming. A great deal of dehumanization in cages was done to large numbers of tiny children at China Lake Naval Facility.

Colorado Springs,CO--The ALEX system programming and end-times Military programming is coming out of Colorado Springs and is connected to NORAD.

Ft. Campbell, KT

Ft. Detrick, MD--involved with medical/biological experimentation

Ft. Hood, TX--programming involving military uses of Delta Monarch slaves was done here.

Ft. Knox, KT --

Ft. Lewis, WA--involved with the Psychic warfare part of the Monarch Programming.

Grissom AFB, IND--

Homestead AFB, FL--

Kirkland AFB, NM--

Lampe, MO--This has been the site of a CIA near-death trauma center where slaves are programmed. It is an R&R center for the CIA where they can have any sexual perversion or drug they want. This has been a large cocaine supply depot also. Hal Meadows was director of this center which is deep in the woods surrounded by cabin chalets overlooking a small deep lake. A gravel road leads to the site which is fenced and well-guarded. Hal Meadows address was Box 27, Lampe, MO 65681.

Langley, VA-- Slaves for the wants of intelligence.

Las Vegas (sites in and around Las Vegas), NV--MGM's Grand Hotel and Theme park were built for programming, but there are also some sites outside of the city used. In the general area of Las Vegas in remote sites, the elite gather for slave auctions once a year where Monarch slaves are sold and traded. The Mob is involved with Monarch slaves in Las Vegas.

McClellan AFB, CA - Very bad Child and adult porn using Monarch victims is distributed through this base as well as the other bases listed in this list. A T.W. Sanderson worked with Monarchs at this base.

MacDill AFB, FL --

Maxwell AFB, AL --

Montreal, Que., Canada -McGill Univ., McGill Psychiatric Training Network, Allan Memorial Inst., St. Mary's Hosp.- The Zombie Room (Sleep Room) in the basement, the Isolation chamber and the Grid Room at St. Mary's Hospital were used for programming.

Mt. Shasta, CA--Underground facilities around this hugh mountain in the Lake Shasta area are putting out Monarch programming that makes the people think they are in

communication with aliens. This facility is for torturing & reprogramming captured runaway Monarch slaves. People are brought into the area via helicopter, plane, or flying saucer.

Nashville, TN–These sites work with the Country Western Music Industry which is actually a CIA front for moving drugs to finance their dirty black activities

Papillion, NE

Patrick AFB,

Portland (Old OMSI, New OMSI, Bldg. near Monarch Hotel at 8800 SE Sunnyside Rd., Mormon Temple, etc.), OR. The Old OMSI building had a back door on the west side in which slaves were taken in to the bottom floor and reprogrammed. The DC-3 airplane outside of the building was used in the programming as a hypnotic trigger. The submarine docked outside of the new OMSI building is also used as a programming hypnotic tool. The new Mormon Temple has an extremely high tech underground tunnel facility for programming built underneath it.

Presideo, CA (incl. Alcatraz, San Francisco)-- The Illuminati and various Satanic cults used the Presideo for their programming. Split-brain & other programming was done at Letterman hospital. Fort Point was used for Illuminati ritual & programming, as well as a number of churches, underground gun emplacements and the large circular Greek column art building at the Presideo. Alcatraz, abandoned as a prison, was used for water tortures and other programming. Tunnels connected buildings, and the Mule/Horse buildings and the cemetery also were used. This is one of the older programming sites. Psychic warfare activity also was experimented on in this area.

Redstone Arsenal, AL--

San Antonio, TX--

Salt Lake City (Mormon Temple)-- This underground facility works in conjunction with the Mormon hierarchy who are allowed to create slaves. The Illuminati put in base programming that still gives them ultimate control beyond the control that the Mormon programming has.

Scotty's Castle, Death Valley, CA- Mengele (Dr. Green) programmed in some of his "internal boxes", as well as other Illuminati programming was done at this site.

Tinker, AFB, OK--Tinkerbell programming is carried out here. This programming makes alters think they are like Tinkerbell in that they will never grow up or age.

Tulsa, OK--Believed to have an Alice In Wonderland theme to their programming.

Washington, D.C. area--The basement of the Pentagon and other facilities around Washington D.C. such as the Jesuit Georgetown Univ. Hosp. are involved with Mind-Control. Presidential Models are moving in and out of Washington, D.C. carrying messages and performing their sexual acts for the lusts of politicians.

Youngstown, OH--The Youngstown Charm School has been run by Illuminatus Prosser Seward Mellon along with a U.S. Congressman named Jim Trafficant. This school is for Beta models and gives them advance sexual charm training. This school produces about 6 new Monarch slaves every three days. Mafia deals are carried out on the second floor of the charm school.

UNDERGROUND

Bases and Tunnels

What is the government trying to hide?

Richard Sauder, Ph.D.

There are more underground bases than you think, and there's more going on than just planning to keep the President alive in a nuclear war. Working from public documents and corporate records, this book digs below the surface of the government's super-secret underground!

50 Pages of Photos and Illustrations!

PLUS ADDITIONAL CHAPTERS ON UFO-LIKE TECHNOLOGY

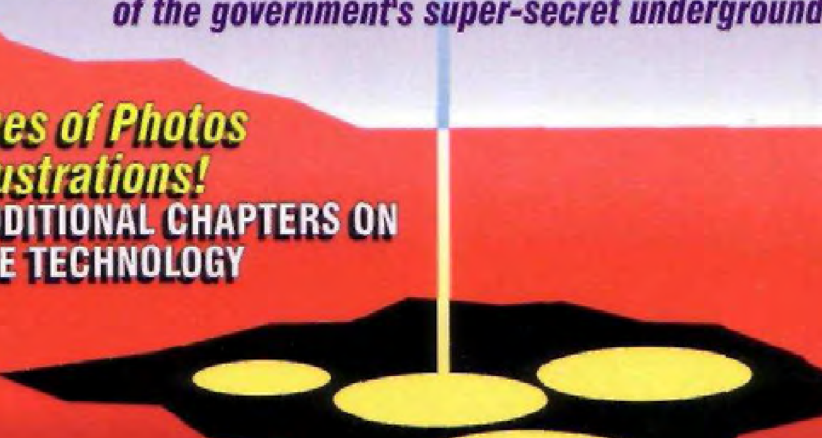


Table of Contents

Foreword: A Cautionary Note To UFO Buffs..............................5

1. Oh Yes, They're Real!.. 10

2. The Military Underground: Air Force, Army and Navy 21

3. The Ultimate War Rooms: Fighting the Big One From Deep Underground..43

4. More Underground Facilities: Military, Government, Nuclear and Business..62

5. The Mother of All Underground Tunnels? 72

6. Tunnelling Machines: The Conventional Types and the Science Fiction "Black" Models 84

7. Nuclear Testing, the EPA, Abductions, Animal Mutilations (and Aliens?)...103

8. Abductions, Needles and Implants: A Fresh Approach...112

9. Is the U.S. Military Involved in "Alien" Cattle Mutilations? 121

Afterword: Last Words On Underground Bases, Tunnels and Exotic Tunneling Machines..126

Illustrations...The Middle Section

Footnotes 131

Index...139

Foreword

A CAUTIONARY NOTE TO UFO BUFFS

Persistent rumors of secret underground bases and deep underground tunnel systems have swirled through the field of UFOlogy for some years now.

These underground installations are variously said to be constructed, staffed and operated by covert human agencies (either part of the military-industrial complex or various federal government agencies), or by extraterrestrial or alien beings (the so-called "Little Greys" often mentioned in the UFO literature), or by both covert human agencies and aliens working together in secret, underground installations.

I will say at the outset that my research has not revealed whether or not Little Greys even exist, much less whether or not they are living and working in underground installations. Perhaps the Little Greys really do exist; perhaps they do not. But since I cannot definitively answer the question one way or the other, I will not deal with it to any great degree in this report. Neither will I discuss reported cases where abductees have been taken into purported underground installations, where they have allegedly seen and experienced many strange things, including bizarre medical procedures and biological engineering experiments. Though I have both heard and read such stories I cannot testify as to the veracity of these reports, so I will not concentrate on them here. These anecdotal accounts are interesting, however, and I am

keeping an open mind about them.

What I do know for certain is that there are many underground installations here in the United States.

I also know that the military-industrial complex and various federal government agencies have constructed, and are working in, many of these installations.

I also know that throughout virtually the entire post-WW II period (and perhaps before) the United States government has been actively planning and constructing underground facilities and installations, some of which are very deep underground, quite sophisticated and capable of accomodating large numbers of people. I have documented quite a number of these facilities and will describe them, to the extent that I am able, in this book. I have also been told of many other underground facilities that I am presently not able to document. For that reason, most of them will not be discussed here.

I have been able to find considerably less information about the much-rumored tunnel system said, by some reports, to crisscross the United States. This does not mean that it does not exist. It may simply be that its deep underground location (if it really exists) gives it a natural cover that is hard to break. Or maybe it really does not exist! I don't know for sure one way or the other. Whatever the case, I will present what information I have uncovered about tunneling technology and tunnel systems - the kind of information that may well form the popular basis for the rumored underground tunnel system.

My approach to the tunneling and tunnel network issue is the same as to the underground base question: I will present for my readers reports, information and facts that I have discovered and leave them to draw their own conclusions. I trust that most of what follows will be as

new and intriguing for others to read as it was for me to discover.

I understand that some readers may object to the publication of information about military facilities. However, it is my feeling that the aims and ideals of representative democracy are poorly served by secrecy in government, especially in the policies of the armed services.

History teaches us that when a country has an exceptionally powerful military, and when that military carries out secret policies and agendas like the U.S. military does (think of the illegal Iran-Contra affair, of super-secret nuclear bomb testing in Nevada, of the astronomical amounts of money given to the Pentagon every year for so-called "black projects"), then there is an ever present danger of that military taking control of the government. That control could be taken quickly -- or gradually. Noisily or quietly. But dictatorships are born when power is usurped by the military. God forbid that a military dictatorship should ever march under the stars and stripes of the United States of America. Protection against that ever happening begins with the exercise of our First Amendment right to speak freely.

So, in that spirit, and in the hope that some of what follows will help peel away the cover of excessive secrecy that shields too much of what the Pentagon does from public scrutiny, I offer solid documentation of underground military installations, as well as official plans and documents pertaining to the construction, operation and planning for such installations.

I would like to briefly relate an unpleasant incident involving the U.S. Army Corps of Engineers. In December 1992, while researching this book, I filed a Freedom of Information Act Request with the U.S. Army Corps of

Engineers. My request sought information about the Corps' involvement in underground base and tunnel construction and maintenance. As it happens, I was at that time a PhD candidate in political science working on my doctoral dissertation. After getting no substantive response to my request, I called the Pentagon and was referred to the Army Corps' Freedom of Information Office. I subsequently called that office and complained about the Corps' noncompliance with my request. A few days later an attorney for the Army Corps of Engineers called my dissertation advisor to complain about me. He informed my dissertation advisor that if I wanted to get bureaucratic that he would show me what "bureaucratic" was!

Subsequently I received a letter from the Corps denying my request for a fee waiver and stating that I would have to pay all fees related to searching for and providing documentation on their subterranean construction and maintenance activities. Needless to say, this could easily have run to thousands of dollars.

As a result, that information is not in this report. However, I still found plenty of other information relating to the U.S. Army Corps' underground construction activities and it is all discussed in detail in the pages that follow. So the Army's attempt at suppressing my First Amendment rights was not entirely successful. The free press lives!

Chapters 7 and 9 of this book were first published in UFO Magazine, edited by Vicki Cooper.

Readers are welcome to forward information to me concerning underground installations or tunnels of any sort. The more specific and detailed the information is, the better. Clear photographs, with accompanying details about when and exactly where they were taken, as well as what they depict, are also welcome. Sending photographs

or information to me constitutes permission for future publication or use by me, at my discretion, without further obligation or compensation to the sender. Please request anonymity if you want it. My address is:

Richard Sauder
c/o Adventures Unlimited
Box 74
Kempton, IL 60946 USA

Now, let's go underground -- and see what's there!

RICHARD SAUDER, Ph.D.
January 1995

Chapter One
OH YES, THEY'RE REAL!

Do secret, underground government installations exist? The answer is absolutely, positively - yes. They are real.

In 1987, Lloyd A. Duscha, the Deputy Director of Engineering and Construction for the U.S. Army Corps of Engineers, gave a speech entitled "Underground Facilities for Defense -- Experience and Lessons." In the first paragraph of his talk he referred to the underground construction theme of the conference at which he was speaking and then stated: "I must deviate a little because several of the most interesting facilities that have been designed and constructed by the Corps are classified." Mr. Duscha subsequently launched into a discussion of the Corps' involvement, back in the 1960s, in the construction of the large NORAD underground base beneath Cheyenne Mountain, Colorado (See Chapter 3 for a more detailed discussion of the NORAD installation). And then he said: "As stated earlier, there are other projects of similar scope, which I cannot identify, but which included multiple chambers up to 50 feet wide and 100 feet high using the same excavation procedures mentioned for the NORAD facility."[1]

I submit that you will probably not find a more honest admission anywhere by a military officer that the Pentagon has, in fact, constructed secret underground installations.

Given such an explicit admission, within the context of the paper trail that the military has left over the last 35 years (set out in this book in considerable detail), and the stories that I have heard from other individuals, I consider it an absolute certainty that the military has constructed secret underground facilities in the United States, above and beyond the approximately one dozen "known" underground facilities listed elsewhere in this book.

Just a few of the many places where these underground facilities are alleged to be are: Ft. Belvoir, Virginia (home of the Army Corps of Engineers); West Point, New York (site of the Army's officer training academy); Twentynine Palms Marine Corps Base, in southern California; Groom Lake or Area S-4, on or near Nellis Air Force Base, in southern Nevada; White Sands Army Missile Range, New Mexico; under Table Mountain, just north of Boulder, Colorado; under Mount Blackmore in southwestern Montana and near Pipestone Pass, just south of Butte, Montana. I would be glad to hear from individuals with information about any of these alleged facilities.

But not all underground installations are secret military projects. Many underground tunnels and facilities have been built that are not covert in any way. There are numerous highway and railroad tunnels, and many major cities have extensive subway systems. There are also miles of utilities, such as water lines and sewer tunnels, with accompanying pumping stations.

Some of the most complex, non-covert underground facilities that have been built are for hydroelectric powerhouses. The rooms and halls in these kinds of plants can be hundreds of feet below the surface and quite huge in some cases. For example, the powerhouse at Portage Mountain Dam in British Columbia, Canada is 890 ft. long,

66.5 ft. wide and 152.5 ft. from top to bottom. Of special note is the method used to deliver concrete to the powerhouse chamber during construction. An 8-in diameter pipe was run 400 ft. from the ground surface down to the construction area, and the concrete was delivered through the pipe.[2]

But if such extraordinary human ingenuity and effort can bring into being the tunnels through which we freely drive our cars, and the power stations which deliver electrical power to our homes, it requires no great stretch of imagination to suppose that installations of similar, or even greater, size, complexity and depth could have been built underground, perhaps covertly, by agencies of the United States government and huge corporations. As this book reveals, our government - and the contractors with which it works ~ has the personnel, technical know-how, machinery and money to plan and complete mammoth underground construction projects.

Where are the bases?

In the pages that follow I will list, one by one, as many of the known underground facilities in the United States and Canada that are operated or maintained by United States government agencies and major corporations as I can presently document, reporting as much information about each one as possible. For some, I can report only that they exist; for others, I can say a good deal more. As it happens, there are many similar deep underground facilities in other countries. Sweden, Switzerland, France, Saudi Arabia, Israel and Russia are known to have sophisticated underground installations -- and, presumably, yet other countries have them as well. In this book I will restrict my discussion only to North American facilities.

So there is no question that secret underground bases

exist. But how do they get there? How is it possible to plan, build, and operate them, all in secrecy? As it happens, it is easier than the average person might suspect.

In 1985 the U.S. Army Corps of Engineers published a report entitled Literature Survey of Underground Construction Methods for Application to Hardened Facilities. The report concluded that, "Since adequate technology is available to construct hardened underground facilities under virtually any ground conditions, the main constraint in construction projects remains economic viability rather than technical feasibility." In other words, with enough money, underground facilities can be built almost anywhere. Given the huge buildup in military budgets under the administrations of Ronald Reagan and George Bush one cannot help but think that "economic viability" -- money ~ may not have been a drawback at all, especially for projects done beginning in the early 1980s.

In very general terms the Army Corps report discusses a variety of types of underground facilities and construction techniques. Two of the types of underground facilities it discusses are (1) deep shaft structures and (2) tunneled structures in mountainsides.

Inspect Illustration 1.[3] Notice that tractor trailer trucks are depicted as entering both kinds of structures. In the mountainside facility the truck appears to drive in through a tunnel. In the deep shaft structure truck entry appears to be via an access building and some kind of vertical hoist or elevator that would seem to be implicit in the layout of the facility. The deep shaft structure is also shown with an accompanying ventilation shaft to the surface, which has its topside terminus in a "protective enclosure."

How To Hide An Underground Base

To illustrate just how well hidden such underground

facilities -- and the entrances that give access to them - can be, consider the examples of two actual, underground installations. One of them is in England, the other in Sweden. First, the Swedish installation:

In central Sweden there is an underground factory excavated deep into a granite mountain which employs nearly 3,000 workers and manufactures diesel and gasoline engines, agricultural machinery, and various machine tools. As you approach this installation, the only man-made structure apparent to the unaccustomed eye is an innocent looking Swedish farm house, located at the foot of a hill. However, when the hinged walls of this house swing open, much like large garage doors, there is an opening of sufficient size to accomodate large trucks.[4]

Consider that these words were written in 1949, during the immediate post-war period. If in the 1940s the Swedes could disguise the entrance to a major, underground, industrial facility as an ordinary farm house, what might the Pentagon be capable of today? Clearly, the possibilities are extensive.

Now for the English example. Until 1989 the War Headquarters of the British Army's UK Land Forces Command was situated in an underground bunker 50 ft. below a field in Sopley, Hampshire. When it was active the sign in front of the installation identified the place as a "training area" for the "No. 2 Signals Brigade." (This is more than a little reminiscent of the two U.S. Army "Warrenton Training Center" stations mentioned later.) The English bunker has now been replaced by a newer facility elsewhere, but the interesting thing about the now abandoned Sopley facilities is how nondescript the entrance is.

On the surface, only a guardhouse and two ventilator shafts now stand in an empty, but fenced-off field ... A shaft concealed at the back of the innocuous looking guardhouse gives access to a stairwell and underground tunnel -- at the end of which is a two-story bunker with about 50 rooms.[5]

I strongly suspect that the designers here in the United States have been at least as ingenious as their counterparts in Europe in disguising and concealing entrances to underground installations. Virtually any house anywhere, or any building, large or small, is capable of concealing an entrance to an underground facility. This is not the same, of course, as saying that every house and building that one sees is, in reality, a disguised underground base entrance. Still, as the above examples show, some houses and buildings certainly can be disguised entrances for such facilities. Since they don't have signs on them advertising the fact, the hard part is figuring out which ones they are. To say that this is not easy is an understatement.

Starting Construction: One Case History

So underground bases do exist and they can be hidden. But how do underground construction projects get underway in the first place, without being noticed?

Consider Kennesaw Mountain, just outside of Marietta, Georgia, in the late 1950s, and Green Mountain, on the outskirts of Huntsville, Alabama.

Two articles in 1957 reported that the Army was planning to build a huge underground rocket factory inside Green Mountain. The project was to have been undertaken jointly by the American Machine and Foundry Company, the Redstone Arsenal and the Army Ballistic Missile Agency. In addition to the missile plant, the facility was

also slated to have a "sort of subterranean 'junior Pentagon' where elaborate headquarters would be installed to direct the defense of the southern U.S. from enemy attack." A local group bought 200 acres along the Tennessee River for docks from which a company called Chemstone would ship the limestone excavated during construction to market.[6] This same group, comprised of members of the Huntsville Industrial Expansion Committee, also engaged in a nearly two-year "series of obscure real estate transactions" in which they purchased, "in their own names or through proxies, various parcels of land scattered about ... Green Mountain"[7] for the construction of the underground, military-industrial facility.

I don't know if this base was ever actually built (if you do, please contact me). But whether or not it actually moved to the construction phase is beside the point here. It is fascinating enough to see how a site is selected, bought and prepared for construction.

The preparation and preliminary work proceeded in a most interesting fashion, in that, even though it was to be a combination underground "junior Pentagon" and U.S. Army missile factory, the land for it was actually purchased not by the Department of Defense, but by private citizens, acting on their own or as proxies for others. The plan for the facility is also intriguing in that, as of 1957, it clearly showed the kind of military-private industry cooperation that has today become commonplace. In this case, it involved the U.S. Army and the American Machine & Foundry Co.

So already in 1957 the Pentagon - and local business interests -- showed themselves capable of coming together to plan the construction of a major underground military facility, to be built inside of Green Mountain, in the

southern Appalachians, just outside of Huntsville, Aalabama. That nexus of interests was comprised of (a) big business; (b) military agencies; and (c) private individuals who were in on the deal (and who very likely benefitted from insider speculation in the local real estate market). Underground base researchers would do well to look for this nexus of interests and pattern of activity elsewhere, as similar groups are likely to have played key roles in planning and constructing underground facilities in other places.

Here is the way I see the actual construction scenario playing out: military agencies desire to construct underground facilities as secretly as possible. The Army Corps of Engineers can supervise the actual construction and draw up the plans, but special expertise and equipment will often need to be supplied by private industry. And specific or highly technical industrial operations will likely need to be conducted by private companies as well. Although the Pentagon and other federal agencies (notably the U.S. Forest Service, National Park Service, Bureau of Indian Affairs, and the Bureau of Land Management) control huge tracts of land in the West, in other parts of the country most of the land is owned by private citizens. So if a military agency wishes to secretly construct a base on a piece of land that it does not own, in order to avoid drawing attention to its plans, it might covertly employ a sympathetic group of private citizens or businessmen to handle the real estate transaction(s) for it. In this way, the military gets its land, but without unwanted publicity and fanfare.

The Air Force Times announced in 1959 that the Air Force was on the verge of agreeing with the U.S. Department of the Interior to place an underground SAGE radar facility inside of Kennesaw Mountain (the mountain

was, and is, a National Park owned by the Interior Department), on the outskirts of Marietta, Georgia. Construction was projected to last two years and to cost about $15 million (in 1959 dollars). The facility was to be a "semi-automatic Air Defense Center" for the surrounding 13 state region.[8] I do not know if this installation was ever built. The mountain is only a few miles from Dobbins Air Force Base, so it would have been possible to drive a tunnel the short distance from Dobbins AFB and excavate the inside of the mountain without disturbing the surface of the national park in the slightest. All of the heavy machinery required to build the facility could have entered and exited the underground construction site via Dobbins AFB.

Whether this was in fact done I do not know. But even if neither the Kennesaw Mountain nor the previously mentioned Green Mountain underground facilities were ever constructed the mere fact that plans to do so were announced demonstrates that the Pentagon, as of the late 1950s, was actively planning for underground bases in the southern Appalachian region. Not only that, but the plans were in an advanced stage of preparation. (Turn to Illustration 2 to see how military planners in the late 1950's were visualizing their underground bases.)

So even if these two particular facilities were not built (and I do not know one way or the other) my research leads me to believe it is likely that others were built in northern Alabama and Georgia, and in the Carolinas, and perhaps in Tennessee as well.

Of course, major underground projects would probably get underway in much the same way in any other state or region of the country.

Supplying Power to Underground Military Facilities

A primary consideration in the construction of deep-underground facilities is obtaining sufficient power for operation once the installation is built and functioning. By the early 1960s the U.S. military had decided that "... either of two prime power plant systems would provide suitable sources of electrical power for hardened, underground Command Centers. These two are the diesel power plant and the nuclear power plant."[9] While it may seem possible to plug into the commercial network that services most of the country for the electrical power needs of underground facilities, a 1963 Army report concluded that the power requirements of these installations can be sufficiently unique, due to "stringent voltage and frequency requirements which may be imposed by special electronic equipment," and due to the necessity of power self-sufficiency under emergency conditions, "that it is far more satisfactory, and in many cases more economical, to provide a generating plant within the installation itself to serve all the load and to eliminate any connection to a commercial power source."

The 1963 Army report concluded that "...nuclear power plants appear to be advantageous for use in underground installations." And it effectively endorsed their use in underground military installations: "...(N)uclear power is the only field tested, non-air-breathing system with sufficient electrical generating capacity to support an underground installation of the size and type envisioned." The report then proceeded to discuss the pros and cons of various power plants, most of them conventional, before concluding with a list of the various nuclear power plants already built, under construction or being designed for military use.[10] However, the report

unfortunately did not specify for what size and type underground installation these power plants were intended, or where the facilities may be located. But the very existence of an Army Corps of Engineers manual entitled Utilization of Nuclear Power Plants in Underground Installations means it is entirely possible that underground military facilities may be powered by self-contained nuclear power plants.

In the case of diesel power plants, during emergency "button-up" periods when the installation would be sealed from the outside world, there would be a so-called "closed-cycle" system in operation. This system would utilize sodium hydroxide for disposal of carbon dioxide in the exhaust produced by the diesel engines; liquid oxygen stored in cryogenic tanks for combustion of the diesel fuel; and fuel oil to power the diesel engines, stored in an underground depot, and replenished as needed from tanks on the surface.[11]

Other proposals that have been advanced to generate independent power economically are detailed in Chapter 5.

The secret underground bases exist; they can be well hidden; and they can be independently powered.

In the next chapter I take the reader on a guided tour of underground bases throughout the United States. No doubt the locations of some of these bases will be a surprise to many!

Chapter Two

THE MILITARY UNDERGROUND: AIR FORCE, ARMY AND NAVY

It is important, first of all, to realize that the United States military has been heavily involved in underground construction for decades. I will set out for you as many of the locations where the various military agencies have actually constructed major underground facilities as I can presently document. I have been told of, and have read of, many others. While I think it highly probable that at least some of these other secret installations may exist I will not discuss most of them in this report, because I cannot presently document them.

I will also discuss at some length planning documents generated by various military agencies pertaining to construction and operation of underground bases and tunnel systems. These planning documents are real. They were written over a 25 year period beginning in the late 1950s and continuing up to the mid-1980s. The reader will have to be the judge of whether any of the underground facilities discussed in the planning reports have been constructed. I personally have not been in any underground military facilities and am not privy to classified information; however my hunch is that some of the facilities mentioned in these reports and studies probably were built.

The Air Force and Project RAND

One of the most prominent names in the early history of U.S. government planning for underground bases is Project RAND. The RAND Corporation became operational in November 1948. It actually grew out of U.S. Air Force Project RAND, which was established in 1946 to carry out long-range research projects of interest to the Air Force. The mission of the RAND Corporation was to work on cutting edge problems in the realms of engineering, economics, mathematics, physics and social science.

In the late 1950s, one of the problems that the RAND Corporation was working on was the question of underground base construction for the United States military. Accordingly, Air Force Project RAND and The RAND Corporation held a symposium on this topic, on 24-26 March 1959, to which they invited a wide variety of technical experts from the public and the private sector. According to the chairman, the purpose of the symposium was to discuss "the problems of protecting military installations located deep underground or under mountains" in the event of nuclear war.

He went on to say that for the two years previous (since 1957) The RAND Corporation had been "actively investigating the need for a small number of superhard deep underground centers" that could withstand the fury of a massive nuclear attack.[1] The two-volume report itself is made up of dozens of papers about tunneling, underground excavation, geology, engineering technology and the like. Most of the papers are quite general.

The major importance of this RAND Corporation sysposium, however, is that it reveals that already in the 1950s the U.S. government was actively planning for the construction of underground bases and installations. (In fact, as I shall show later, already in the 1950s the United

States government had constructed a number of secret, deep underground installations.)

Also noteworthy is the way in which the groundwork for the move underground was prepared: The RAND Corporation called on experts from military and nonmilitary government agencies, from the corporate world and from major universities. Chairmen for the individual sessions were drawn from Princeton University; RAND Corporation; Colorado School of Mines; Army Corps of Engineers; University of Illinois; National Bureau of Standards; Ballistic Research Laboratories; Brown University; and an assortment of independent consultants and private firms. This pattern of collaboration on underground construction projects between university researchers and university engineering schools, private sector industry and the military and other government agencies is one that has continued right up through the 1980s.

In 1960 the RAND Corporation published a study under contract to the Air Force in which twelve specific locations across the country were selected as possible sites for deep underground installations. In this RAND Corporation report, all installations are assumed to be more than 1,000 ft. underground.[2]

One of these sites, on the Keweenaw Peninsula near Calumet, Michigan, was selected for its location under places where previous hard rock mining had occurred. The theory expressed in the report was that in the event of a nuclear attack, seismic waves from the detonation of nuclear weapons on the surface would be attenuated and deflected by the previously excavated shafts, tunnels, drifts, rooms and chambers of the copper mine workings, thereby shielding the underground installation from the full brunt of a nuclear explosion. In the cases where such

mine workings did not already exist, so-called "umbrellas" could be excavated above the installation. These are open spaces in the rock that would serve the same purpose of protection as mine workings.[3]

Another site where a facility was proposed was under an abandoned iron mine near Cornwall, Pennsylvania.[4] Other sites proposed for deep underground military installations were Mohave and Coconino Counties, Arizona, under the Grand Wash and Vermilion Cliffs; a limestone mine near Barberton, Ohio, about 8 miles from Akron; The Book Cliffs near Rifle, Colorado, where the federal government already has excavated an oil shale experimental mine; the area near Morgantown, West Virgina; the area of McConnelsville, Ohio, between the towns of Marietta and Zanesville; the northwest corner of Logan County, Illinois, about 25 miles south of Peoria; an indeterminate location in southwestern Minnesota; the thick diatomite strata of Santa Barbara County, California; and lastly, and perhaps most interestingly, under the glacial ice and rock of the Kenai Peninsula in southern Alaska. In the last two cases, it was felt that the chalk-like diatomite and the glacial ice would help absorb the considerable force of a nuclear blast and thereby afford a greater measure of protection to the deeply buried facility.[5]

While I do not know if the Air Force has constructed underground installations at the 12 locations specified in the RAND report, there is no question that the Air Force does have underground installations that can be documented. One such facility, little known, is in operation near Albuquerque, New Mexico. The site is referred to as the Kirtland Munitions Storage Complex by the Air Force, which for years would not comment on what was there, though speculation was rampant that the complex was a nuclear weapons storage area.

In 1949 the Air Force dug into one of the ridges in the foothills of the Manzano mountains near Albuquerque and began to fill it with tunnels and caverns.

One of the miners who helped excavate the complex personally told me of blasting out large chambers underground, 40 ft. wide, 30 ft. high, and 100 ft. long. Security during construction was so tight that as soon as his crew completed a tunnel or chamber they were pulled out and sent away to excavate another portion of the mountain. This was compartmentalization of the most literal kind, intended to ensure that not even the miners who built this underground base would be familiar with its complete layout.

The miner further told me that this facility contains a covert, subterranean, nuclear weapons assembly plant. Another man I have spoken with who has been inside the facility told me that it seemed to him that the mountain contained miles of tunnels. This second man also said that there was a secret nuclear weapons assembly plant inside the mountain (See Illustration 3).

Security at the facility, which is clearly visible a couple of miles to the south of 1-40 on the eastern outskirts of Albuquerque, is extremely tight. The 3,000 acre base, actually a separate base within the Kirtland AFB/Sandia National Laboratories complex, is ringed by a 9.5 mile concentric band of four, tall, chain-link security fences, the third of which carries a lethal electrical charge, and the fourth of which is topped by coils of razor-sharp concertina wire.[6] Entrance to the facility is via secure blast doors set into the mountain. Until recent years, armed police in jeeps patrolled the perimeter around the clock.

In 1989 the Air Force began construction of a second underground facility within sight of the Manzano Base. The new facility, completed in June of 1992, is also on land

controlled by Kirtland Air Force Base. 95% of the new, 285,000 sq ft. bunker is below ground.

I was told by one of the Marine guards at the new facility that in addition to more prosaic security measures such as magnetically coded ID cards there are also devices that scan the palm print and retina of the eyes of each person seeking entry. But he would tell me no more about the facility than that.

According to the Air Force, whatever used to be in the Manzano complex has now been transferred to the new underground bunker. However, this sheds little light on what was transferred to the new bunker since Air Force officials have never in the first place discussed what used to be in the Manzano complex. And although the Air Force may have announced that it has vacated the mountain, it is hardly empty. A recent report indicates that the Department of Energy (DOE) now occupies 50% of the Manzano bunker complex. But like the Air Force before it, the DOE is not commenting either about what it is doing in the Manzano base. Nuclear arms experts speculate that nuclear weapons are being stored in both the new bunker and the old Manzano base.[7] And they may well be right.

On the other hand, even supposing that nuclear weapons are in either or both of these underground bunkers, it is still entirely possible that something more than weapons storage is happening below the surface at Kirtland. Indeed, if my two sources are correct there was in the past, and still may be, a secret nuclear weapons assembly plant underground, beneath the foothills at Kirtland Air Force Base.

Knowing from published newspaper accounts in the local Albuquerque Journal that the Department of Energy (DOE) had moved into 50% of the large underground facility on Kirtland Air Force Base, I filed a Freedom of Information Act (FOIA) request with the DOE's Wash-

ington, DC office. I asked for information about the underground facility at Kirtland. I also asked for information about other underground facilities rumored to be operated by the DOE at Los Alamos, New Mexico; the huge Pantex nuclear weapons factory near Amarillo, Texas; the Rocky Flats nuclear facility in Colorado; and an unusual electronics facility called "ICE STATION OTTO," located in a very rural area a few miles north of Moriarty, New Mexico on Highway 41.

My request was sent to the DOE's Albuquerque office at Sandia/Kirtland. (Sandia National Laboratories, run for decades for the Department of Energy by AT&T, are now administered by Martin Marietta. Sandia Labs are located on Kirtland Air Force Base.) In their initial response to me, DOE denied that they have any records of underground facilities at any of these sites. Or, in DOE jargon, "no responsive records to your request were located."

Well, that's an interesting response, because the local newspaper has reported actual underground facilities at Kirtland AFB that are fully 50% occupied by the DOE. Once again, a government agency has refused under the Freedom of Information Act even to release information that is readily available in the public domain.

I have been told that there are underground facilities and tunnels at Los Alamos National Labs as well. But the DOE response to my request said that there were none. When I received this response I called up the appropriate DOE personnel and informed them that the FOIA office at Los Alamos was not forthcoming. In reaction to my phone call the DOE again queried the Los Alamos FOIA office. Within a couple of days the DOE at Los Alamos provided a badly blurred photostatic copy of an article by Earl Zimmerman entitled "LASL'S Unusual Underground Lab," which describes an underground laboratory built in the late

1940s (See Illustration 4 for a photograph taken from inside this mysterious facility).[8] But the DOE included no information as to when, or in what magazine or journal the article appeared. At my request the Sandia office again called the Los Alamos DOE office for more information and was told they did not know the facts of publication of the article and that they had no other information about this underground facility.

Hmm.

Isn't it interesting that Los Alamos' first search found no records responsive to my request, but the second search did? As best as I can make out from the barely legible text in the photostat of the article about the LASL, the facility was constructed in 1948-49 by the huge fabrication company of Brown & Root, Inc., of Houston, Texas. The main tunnel was designed by a company called Black and Veatch, of Kansas City, Missouri. It was bored into the cliffside of Los Alamos Canyon, at a place called TA-11 or perhaps TA-41 (owing to the poor quality of the xerox the numbers are indistinct). Opening off of the main tunnel, which was quite large and could accomodate a large truck for nearly 250 feet of its length was a thick vault door, behind which was a high security room, containing five more, thick, vault doors containing multiple combination locks, of the sort that banks have for their vaults. Behind each of these doors was a walk-in vault. The whole complex was "lined with reinforced concrete, equipped with three sources of electric light and power, modern plumbing, forced ventilation and air conditioning." The climate control called for a "constant humidity of about 50 percent and a temperature that remained between 40° and 60°." A spur tunnel led to another room that contained an emergency diesel generator, to supply power in the event that outside sources were cut off. In an emergency

batteries could also provide lighting. The complex was located beneath the Noncommisssioned Officers Club.

The complex was reportedly originally built to store nuclear materials, and later converted to a fall-out shelter, designated as Shelter 41-004 (here again the numbers are indistinct). In an emergency it contained supplies to take care of 219 people for two weeks. According to the article, construction details of the 6,000 sq ft. underground facility were declassified in 1959.

Interestingly, the article says that its vaults are "still used as vaults and security is just as strict as ever." And the article alludes to the facility's use as a "pure physics" laboratory. The article also mentions that the complex was associated with something called "W Division."

In subsequent communications with the DOE I received information indicating that this facility was in active use as recently as the mid-1980s.

The existence of this facility raises many questions. The most logical is: are there other tunnels and other high security suites of vaults and rooms deep under Los Alamos? And in light of persistent rumors of captive "EBEs"[9] held hostage at Los Alamos, was this high security, climate controlled, plumbing equipped suite of vaults really dug into the mesa as a storage site for nuclear materials - or was that just a cover story? Was this complex, instead, actually intended as a high security jail for alien prisoners held against their will, incommunicado behind thick steel doors, deep underground? Certainly the time frame of 1948-1949 is suggestive, since that is the approximate time when one, possibly more, UFOs were rumored to have crashed and to have been retrieved, along with some of their occupants, by the U.S. military.

But perhaps the only secrets being protected here

really did revolve around the infant nuclear industry. After all, in the late 1940s the nuclear age was still in its infancy and Los Alamos was the place where the atom bomb was developed and first produced. So it would have made perfect sense to have a local, high security, underground facility for storing nuclear materials.

Something Old, Something New

Yet another provocative underground Air Force installation has recently been reported in the heart of California's wine country.

Within the last couple of years a secret underground installation has allegedly been covertly constructed near Oakville Grade, not far from Napa, California. Aerial photographs of the entrance to the supposed underground facility, located in rugged, mountainous terrain, show "large cement bunkers with large concrete doors, a new road, freshly graded." There are also eight to ten microwave dishes pointing straight up into the sky, evidently providing satellite communications links. There has been heavy helicopter traffic to the facility, evidently to outfit and provision it. When asked about the flights the Air Force responded that they were a "classified operation." According to a local newspaper the new facility is an "elaborate underground complex designed to hold government officials, scientists and other high echelon personnel in the event of an emergency."[10]

U.S. Army Corps of Engineers

A big player in the underground installation business is the U.S. Army Corps of Engineers -- and the "regular" Army itself.

Given the RAND Corporation symposium in 1959, it is no surprise that in the years 1959-1961 the U.S. Army

Corps of Engineers published a five-part series of training manuals entitled Design of Underground Installations in Rock. I cannot possibly condense the entire contents of these documents here, nor will I cite them all. But suffice it to say that the tone of the series assumes that there already were underground military installations, as of the late 1950s. The manuals are clearly intended for use by military engineers training for the construction and maintenance of underground facilities. Judging from the manuals, the facilities in question were intended for use as command and control centers and survival bunkers for the military brass, in the event of nuclear warfare.

Citing the failure of the Germans and Japanese to recognize early enough in WW-II the strategic importance of placing crucial facilities underground, the Army Corps concluded that it was imperative for the United States to construct vital facilities deep underground. This decison was lent extra force by the destructive power of nuclear weapons which made previous installations obsolete. Significantly, one of the reports in this series, issued in 1961, says, "Vital governmental installations have been placed underground, as exemplified by the Ritchie project."[11]

The Ritchie project is a large, underground, military facility on the Maryland-Pennsylvania border which is discussed in some detail later in this report. The interesting thing here is that already in 1961, in a publicly available document, explicit reference is made to governmental installations (plural) already having been placed underground.

Examples of the sorts of facilities the military was discussing placing underground were: communications centers, fortifications, air raid shelters, staff headquarters and offices, research facilities, shops and factories, and storage areas; and hospitals, kitchens, lavatories and

sleeping areas for the use of the personnel stationed underground. According to the Army Corps, some facilities were to be relatively shallow, while other, "more important equipment and facilities essential to defense may be installed in deeper workings" that "are likely to be long and tunnel-like," occupying "one or several stories." According to the report, such deeper facilities may be several hundred feet underground. Several kinds of facilities are discussed: (a) a simple installation with a single shaft or tunnel; (b) a simple installation with two or more shafts; (c) a simple installation with tunnel and shaft; and (d) larger installations with multiple tunnels and shafts for access and ventilation.[12]

The documents provide several possible schematic layouts for underground installations (See Illustration 5 for one such schematic). In addition to the tunnels giving access to the facilities there are also shafts to the surface for ventilation, heating and cooling, and for exhaust of gases from power plant machinery. The documents also show possible designs and appearances of air-intake shafts for underground facilities (Illustration 6) and how an exhaust system for an underground power plant might look (Illustration 7). According to the report, sewage would be piped out of the facility and treated at a nearby plant. There would also be spray ponds, cooling towers, or other air conditioning equipment visible on the surface in the near vicinity of an underground installation, besides air-intake shafts or vents, and exhaust pipes for the power plant. Water would be supplied both from outside commercial sources and also from wells sunk near or from within the facility. Large reservoirs would be hollowed out underground to provide operational water reserves for emergencies. The facilities discussed in the report would also contain kitchens, snack bars, cold storage areas,

dispensaries or first aid rooms, medical facilities, personnel lounges, barracks, auditoriums and conference rooms.[13]

Readers should keep in mind that these facilities could be almost anywhere and could be quite large. According to the report, they could be constructed inside "hills or plateaus" with concealed shaft entrances (my italics). There need not necessarily be any conspicuous hoist house for a vertical shaft since the "principal parts of a hoist plant may ... be contained underground." Tunnels could be as large as 50 ft. by 50 ft. in diameter and chambers as much as 100 ft. high. In some installations "truck or rail traffic might be important." In such cases provision would have to be made for "narrow-gauge rail transportation" or "single-lane highway tunnels," or perhaps even for "two-track railroad or two-lane highway tunnels" as much as "31 ft. wide by 22 ft. high." And it is possible that quite large entrances to underground facilities could open directly off of major canals, lakes, rivers, bays and even the open sea, since the report says that "...an installation might require entrances for barges or ships." The manual goes on to say that, "Landscape scars, roads, and portal structures (entrances) should be as inconspicuous as possible. Camouflage should be considered." Actual underground layout of the chambers in the installation might be in a parallel configuration with connecting shafts and tunnels as necessary or desired for utilities, ventilation, passageways, etc.; or there might be either "radial chambers connected at center, ends, and at regular intervals to form a spider-web pattern," or "chambers in concentric circles or tangents with radial connections," after the manner of the Pentagon.[14]

Certainly, this series of official Army documents, which explicitly discusses constructing large underground installations, some set inside of hills and plateaus with concealed shafts and portals, and underground hoisting

plants and water wells, perhaps with entrances for barges and ships, and maybe even with tunnels that can accomodate two lanes of truck traffic or two-track railways, ought to give considerable pause to reflect. At the very minimum, they mean that at least as early as the late 1950s the Army was training its engineers to design such facilities. In fact, it seems very likely that the Army has built underground facilities similar to the ones described in the five-report series. It also seems very possible that they may be camouflaged or concealed, and for that reason, hard to detect.

In a three-volume report issued in June and July of 1964 and entitled Feasibility of Constructing Large Underground Cavities, the Army Corps of Engineers sets out 12 sites across the country (See Illustration 8) where it calculated 600 ft. diameter cavities could be excavated, up to 4,000 ft. underground. The ostensible reason for constructing these huge underground caverns was to have been for conducting underground nuclear tests. The idea was to "decouple" the blast by situating the explosion in a huge, deeply buried cavity. In that way, seismic energy produced by a nuclear explosion could be muffled, rendering detection (presumably by the Russians) problematic. Let me emphasize that I do not know whether any of these twelve, huge, very deeply buried cavities were ever excavated. And if they were excavated, I do not know if they were used for nuclear testing or for something else.

If actual nuclear tests were carried out in large cavities, deep underground, which had the effect of greatly attenuating the explosion, making detection by the Russians difficult, then it is possible that detection was difficult for others as well. Conceivably, these others could have been local American citizens who may have merely heard what they thought was a muffled sonic boom, or felt

what they perceived as an unexplained, perhaps unquestioned, short-lived rumbling underfoot. But that is speculation. Maybe the cavities were never excavated. Or perhaps they were excavated, but used for another purpose unrelated to nuclear testing.

In any event, Volume I begins by observing that if the surrounding rock is structurally sound "... construction of a spheroidal cavity at least 200 ft. and possibly as much as 600 ft. in diameter and located 3000 to 4000 ft. below the ground surface presents no unsolvable construction problems." It further concludes that, "... a number of sites are available within the continental United States in which large cavities up to the maximum size considered in this report can be constructed." The authors state that a 200 ft. cavity would require two years and $8.5 million dollars to construct. The relevant time and money for a 600 ft. cavity were calculated at 3 1/2 years and $26.7 million. And all at 3000 to 4000 ft. underground. At the time this report was issued, all of the sites in the western part of the country were on federally owned land, some of them on or near military reservations. Most of the sites were also in regions of low population density.[15]

Interestingly, the first report estimates that construction of a 600 ft. diameter cavity would create about 4.2 million cubic yards of rock, not including the muck (excavated rock and soil) from the construction of the access tunnel.[16] The third report in the series estimates that construction of a 600 ft. diameter cavity and access tunnels would create about 7.0 million cubic yards of muck which could be disposed of in an 80 acre dump area (my italics).[17] Both reports allude to concealing, camouflaging or blending the muck dumps into the terrain, so that construction of the tunnel and cavity would be harder to detect.

Volume I goes into lengthy geological discussions of the various sites. Interested readers should consult the document directly for more detail than can be provided here. I will simply list the 12 sites, giving directions to the planned locations of the underground facilities that are as precise as possible.

SITE 1- YUMA COUNTY, ARIZONA. Access via vertical or inclined shaft. The site is located either in the Gila, Copper or Cabeza Prieta Mountains, or conceivably in all three ranges. Yuma, Arizona lies 40 miles northwest of the central Gila Mts. Ajo is about 25 miles east of the boundary of the general area in question. U.S. Highway 80 and the Southern Pacific Railroad cross the northern part of the area. When the report was issued parts of the area were controlled, respectively, by the Yuma U.S. Marine Corps Air Station, the U.S. Air Force Gila Auxiliary Air Force Base and a wildlife refuge.

SITE 2- MOHAVE COUNTY, ARIZONA. Access via vertical shaft. The location is in the east-central Hualapai Mountains (Gila and Salt River Base Line and Meridian). The site is reached by a secondary road that heads south along the base of the range from Arizona Highway 93. Kingman is about 30 miles northwest.

SITE 3- INYO COUNTY, CALIFORNIA. Access via inclined shaft. The five potential sites are located in the Argus Mountains and near the town of Darwin. The report says the two most important locations, from the standpoint of geological conditions that are favorable for constructing a large, underground cavity, are sites D and E. Site D is 4 miles due west of Darwin; Site E is several miles northwest of Trona, directly under Argus Peak. This is a few miles inside the boundary of the China Lake Naval Weapons Center.

SITE 4- MESA AND MONTROSE COUNTIES, COLORADO. Access via vertical shaft. The areas lie in the Sinbad and Paradox Valleys; two sites, one approximately 30 miles east, and the other about 40 miles southeast, of Moab, Utah. The site in Paradox Valley can be reached from Nucla, Colorado by State Route 90; the one in Sinbad Valley can be reached by State Route 141, out of Grand Junction, Colorado, and an unimproved road along Salt Creek Canyon.

SITE 5- PERSHING COUNTY, NEVADA. Access via vertical or inclined shaft. The site is located in a U.S. Naval Gunnery Range in the Shawave and Nightingale Mountain Ranges. To reach the area take unimproved roads from State Highway 34. Lovelock, Nevada is 30 miles to the east and Fernley, Nevada is south 35 miles.

SITE 6- MESA COUNTY, COLORADO. Access via vertical, inclined or horizontal shafts or tunnels. The location is in Unaweep Canyon, approximately 30 miles southwest of Grand Junction, Colorado. State Highway 141 runs through the area. (See Illustration 9)

SITE 7- EMERY COUNTY, UTAH. Access by vertical shaft.

The area is called Horse Bench and is 10 miles south of U.S. 50, and just to the southeast of State Highway 24. Green River, Utah, is about 10 miles to the northeast.

SITE 8- WINKLER AND NORTHERN WARD COUNTIES, TEXAS. Access by vertical shaft. Located near the small towns of Kermit and Wink, Texas. 50 miles west of Odessa, access is by U.S. Highway 80.

SITE 9- MOHAVE COUNTY, ARIZONA. Access by vertical or inclined shaft. Site is on the western edge of the Grand Wash Cliffs, at head of Grapevine Wash. The location is northwest of Kingman, accessible by secondary roads from U.S. Highway 93.

SITE 10- FRANKLIN COUNTY, ALABAMA. Access by vertical shaft. The site is about 10 miles southwest from Russelville, near the small community of Gravel Hill. U.S. Highway 5 is about 5 miles to the east.

SITE 11- KANSAS AND NEBRASKA GRANITIC BASEMENT AREAS. Access by vertical shaft. No specific site was chosen,
as the region has many useful sites where the geology is favorable for deep underground construction. Red Willow County, Nebraska was chosen as an example.

SITE 12- OGLETHORPE AND PARTS OF GREENE, WILKES AND ELBERT COUNTIES, GEORGIA. Access by vertical shaft. One proposed site is near the community of Stephens, one mile due east of Highway 77 and the Georgia Railroad. There are a number of other potential sites for deep excavation in these counties in northeastern Georgia in a general area that lies about 20-30 miles from Athens.[18]

Any of these 12 potential sites would be fertile ground for research and investigation, even now. I would like to hear from readers who may have information about underground facilities at these locations.

Volume III of Feasibility of Constructing Large Underground Cavities is devoted to an analysis of the cost and constructability of a large cavity 4,000 feet underground, under Argus Peak, or the Southeast Peak, both located several miles to the northwest of Trona, California, within the boundary of the present-day China Lake Naval Weapons Center.

A variety of schemes for access were considered, including vertical and inclined shafts, and long horizontal tunnels, as much as three or four miles in length (See Illustration 10 for the vertical access scheme). The actual facility was planned to be hollowed out from top to bottom, with a spiraling perimeter tunnel and a large

central shaft (Illustration 11). Method of excavation was to be by conventional hard rock mining techniques, using truck mounted mining drills, high explosives, front end loaders, caterpillar tractors, dumptors, etc. Muck (excavated rock) would be removed from underground by either conveyor belts, trolley trucks, mining rail cars, hoists or a combination of rail cars and hoists. Two tunnel sizes for access were considered: (a) 13 ft. in width by 15.5 ft. in height; and (b) 23 ft. wide by 19 ft. high.[19]

I would reemphasize at this juncture that I do not know whether or not any of the cavities discussed in this Army Corps of Engineers document, including the one near Trona, California, were ever excavated. Clearly, a great deal of care and time was invested in this planning study; whether that care and planning translated into actual construction I do not know. I would note, however, that the projected Trona, California site lies just inside the boundary of the China Lake Naval Weapons Center, which has long been rumored to be the site of a massive underground installation. While I cannot speak to the truth of the rumor, I nevertheless find it suggestive that in 1964 the Army Corps of Engineers published a document that sets out in some detail a plan to construct a large, deep underground cavity at that location.

I know from direct experience that at least one U.S. Army facility does exist.

The U.S. Army operates a facility in the northern Virginia town of Warrenton. A reported underground bunker known as the U.S. Army Warrenton Training Center, this very secretive installation is supposedly a Federal Relocation Center for an unknown agency.[20] In fact, when I visited the area in the summer of 1992 I decided that there may possibly be two such sites. There are two U.S. Army facilities there, one on Rt. 802 and the

other on Bear Wallow Road, on Viewtree Mountain. One facility is "Station A" and the other is "Station B". Both have signs out front saying "Warrenton Training Center."

When asked about local, underground installations, the person who gave directions to these facilities said that Station B is believed to be a computing and communications facility (this may well be true, judging by the large antennae towering overhead and the AT&T microwave facility located in a field to the rear). He then added, "but no one knows what goes on at Station A." Unfortunately, if the actions of the guard on duty at Station A when I visited are any indication the Army does not want anyone to find out, either.

As I attempted to snap a photo of the gate area from my car the guard sprang into action and bounded toward me waving his arms and angrily shouting, "No!"

Somewhat taken aback at his reaction, which seemed out of all proportion to an innocent snapshot of a government facility, I asked him, "Why not? I'm on a public right-of-way."

He replied even more forcefully, "Because I said so!" As he spoke those words, three other security personnel standing just inside the gate began to move toward me. Suddenly feeling very much as if I had abruptly been stripped of citizenship in a democratic republic and had crossed over unaware into some grim netherworld ruled by military decree I gave up trying to take a picture and drove away.

Peering through the fence at the back of the installation I did notice that at Station A there are massively thick power cables that descend utility poles from large electrical transformers and disappear underground.

Navy Plans

If the Air Force and Army are going underground, can the Navy be far behind?

The Naval Facilities Engineering Command issued a report in 1972 that discussed placing several sorts of Navy installations underground.[21] The stated reasons for planning for subsurface naval installations revolved around concerns such as cost efficiency, environmental impact of new construction and the severe land pressures facing many Navy bases, which are hemmed in by surrounding cities and towns. The five sorts of facilities the report's authors recommended for underground construction were:

1) administration buildings
2) medical facilities
3) aircraft maintenance facilities
4) ammunition storage facilities
5) miscellaneous storage facilities

Interestingly, while the report is devoted to a discussion of the merits for the Navy of underground installations, there is also a brief, passing mention made of possible needs for "undersea ports" and emplacements that would service a future, submarine Navy. To be sure, I have heard stories and read rumors of undersea Navy ports at various places along both the Atlantic and Pacific coasts of the United States, as well as in the Great Lakes region. Have they been built? Does this 1972 document hint at what is now a military reality? If you know, please send me the relevant information.

The schematic illustration of the underground weapons storage area is interesting (Illustration 12). Notice that there can be more than one level, and that the complex may extend down several hundreds of feet. Presumably,

the network of shafts and tunnels could also be adapted for other uses besides weapons storage. I consider it entirely possible that these sorts of facilities have been built by the Navy.

But the Navy isn't just interested in underground bomb 'n' submarine parking garages. They're also interested in your telephone calls.

The U.S. Navy runs a secret electronics facility near the isolated mountain community of Sugar Grove, West Virginia, on the Virgina-West Virginia line. The purpose of the installation, which works out of a two-story underground operations center, is to spy on microwave communications traffic for the National Security Agency (NSA). This illegal and unconstitutional activity is a serious military violation of civil liberties as set forth in the Bill of Rights.[22]

But if the government doesn't very much care about your rights to privacy, it certainly cares a lot about its own right to secrecy.

Especially when it comes to fighting war.

In particular, the big one.

Chapter Three

The Ultimate War Rooms: Fighting the Big One From Deep Underground

A 1989 article in U.S. News & World Report stated that the Federal Emergency Management Agency (FEMA) and the Pentagon administer approximately 50 secret underground command posts around the country, where the president might flee in the event of a nuclear war. (Although FEMA is perceived as a "civilian" federal agency, in reality FEMA and the Pentagon work closely together.) Each of these underground bunkers is "equipped to function as an emergency White House." The article specifically cites the FEMA "Special Facility" at Mount Weather and the Pentagon back-up facility called Raven Rock, or Site R, located along the Pennsylvania-Maryland border, and operated by Fort Ritchie (see the next page for more on the Ritchie facility). Supposedly, in the event of a nuclear crisis, 1,000 civilian and military officials would be rushed to these secret bunkers. They would take refuge there while the rest of the country muddled through the ensuing radioactive holocaust as best it could.[1] In reality, given the number of secret bunkers cited (50), it seems that the number of personnel who would be evacuated would be considerably higher.

The logical question is: where are the underground command posts and bunkers? The answer is not an easy one, since by their very nature these facilities are hard to

find. To begin with, they are all underground. Some of them are on military bases. Virtually all of them have been constructed behind a veil of secrecy and high security. And all of them continue to operate under considerable security.

Nevertheless, at least a partial answer can be provided, because the locations of some of the underground bunkers are known. And information is also available about the function of some of them and what they contain.

THE PENTAGON, NORTHERN VIRGINIA -- As might be suspected, the Department of Defense has burrowed underneath the Pentagon, in Arlington, Virginia and established a sophisticated facility called the "National Military Command Center."

"SITE R", AKA "RAVEN ROCK" OR THE RITCHIE FACILITY - In the hills of southern Pennsylvania, near the small town of Blue Ridge Summit, is the home of the "Underground Pentagon." Run by nearby Fort Ritchie, since the 1950s the facility has been a major electronic nerve center for the U.S. military. This huge installation, known as "Raven Rock" or "Site R," was blasted out of the native granite known as greenstone and lies 650 ft. below the surface. The 265,000 sq. ft. facility which sprawls beneath 716 acres is comprised of five different buildings in specially excavated separate caverns. It normally is staffed by about 350 people. Access to Raven Rock is by way of portals set into the mountainside. Its corridors are lit by fluorescent lights and it contains a wide variety of amenities including a convenience store; barbershop; medical, dining and fitness facilities; a subterranean reservoir that contains millions of gallons of water; a chapel; 35 miles of telephone lines; and six 1,000 kilowatt generators. "Site R" has long functioned as a sort of second Pentagon and is

equipped as a supercomputing and electronic command post linked with numerous military communications networks all over the globe. Local rumor has it that "Site R" is connected by tunnel to the presidential hideaway at Camp David, several miles away in northern Maryland, near the town of Thurmont. According to a recent press report, with the thawing of the Cold War "Site R" has gone to a standby status and will be staffed at a lower level than in the past.[2]

THE WHITE HOUSE, WASHINGTON, D.C. -- There is a large, sophisticated bunker complex under the basement of the White House in Washington, D.C. Dating back at least to the Eisenhower administration, special forces were ready to tunnel down and extract the President from deep underground in the event a nuclear holocaust reduced everything above to rubble.

But just how extensive - and deep - is this complex? One source I have personally interviewed claims that there are many, many levels below the basement of the White House, that keep going down and down. On one occasion during the Lyndon Johnson administration (in the 1960s), this source was sent to deliver some papers from the Department of Housing and Urban Development (HUD). Upon arrival, my source was escorted by two Secret Service agents to an elevator in an area of the White House that is not open to the public. They entered the elevator and went down for what the source remembers as 17 levels. When the elevator doors opened they stepped out into a corridor covered on the walls, ceiling and floor with beige, ceramic tiles. The corridor was very long, stretching away in the distance to the vanishing point. According to my source, other corridors and doors opened off the main corridor. The fluorescent lighting was recessed in the ceiling. There was a man sitting at a desk by the elevator

doors. The papers were delivered to a man in a room that opened off of the corridor and then my source was escorted back to the elevator, back to the surface and out of the White House. All of the men appeared to be Secret Service agents and were dressed in dark, business suits. The person who related this story to me had the impression there were even more levels below the 17th level. Why papers from HUD had to be delivered to the subterranean bowels of the White House, my source did not know. Whatever the actual size of this underground installation may be, clearly there is far more to the White House than is apparent from driving by on Pennsylvania Avenue.

KANEOHE, HAWAII -- There is also an underground installation at Kaneohe, in Hawaii, connected with U.S. Pacific Fleet operations.

CAMP DAVID, MARYLAND -- At the presidential retreat in northern Maryland, there is "an ultrasensitive underground command post" for the use of the president in an emergency. During the Eisenhower administration this command post was run by a group of military officers known as the "Naval Administrative Unit."[3]

OMAHA, NEBRASKA -- And at Offutt Air Force Base, in Omaha, Nebraska, there is an underground command post for the Strategic Air Command.[4]

Unfortunately, I know little more about these installations than I have set forth here. And that's just the point -- I'm not supposed to know, and neither are you. In the event of nuclear war, we'll be nuclear missile fodder while the President and the Joint Chiefs of Staff huddle underground figuring out how to bounce the rubble one more time. For that type of arrangement to work, you need secrecy, and lots of it.

In a time of nuclear war, or during some other crisis,

when the politicians and military planners go underground, where will they get the information they need to make decisions? Some of the most important information will come from — you guessed it - other underground facilities, among them the NORAD facilities described below.

NORAD AT CHEYENNE MOUNTAIN, COLORADO -- For subterranean privacy, try Colorado Springs, Colorado, where the North American Aerospace Defense Command (NORAD) operates perhaps the best known of the major underground bases.

This super-secret facility is located deep inside Cheyenne Mountain, outside of Colorado Springs, Colorado. Here's where the latest space, missile, and air-traffic information is gathered, using state-of-the-art equipment, and fed to military and civilian decision makers.

Planning for the subterranean, 4.5 acre, 15 building complex began in 1956. Construction was started in 1961. The Utah Mining and Engineering Company of San Francisco did the excavating, under the supervision of the Omaha District of the Army Corps of Engineers. The large engineering firm of Parsons, Brinckerhoff, Quade and Douglas was also involved on the project. In 1966 NORAD moved in and began underground operations.

Jointly staffed by United States and Canadian military personnel, the installation constantly monitors all space traffic in and around the earth, all missile launches worldwide, submarine movements and air defenses for North America. This NORAD base is also the National Warning Center for the Federal Emergency Management Agency (FEMA). This is the place from which civil defense warnings for Canada and the U.S. are initiated.[5]

About 1,700 personnel operate the facility around the clock, including a night shift of 300 people. A 4,675 ft.

tunnel bores straight through the mountain. The entrance tunnel is 22.5 ft. high and 29 ft. wide, while the central access tunnel, that branches off the entrance tunnel, is 25 ft. high and 45 ft. wide. Three hundred and fifty hardrock miners, working in three shifts, excavated almost 700,000 tons of granite to construct the facility. The NORAD base is stocked with 30 days of contingency supplies, including enough fuel to run its six diesel generators for 30 days. It also has underground reservoirs, hewn out of solid rock, that hold six million gallons of water for cooling purposes and for use by personnel for domestic purposes. Its 25 ton, hydraulic-operated blast doors, that open off of the access tunnel, well inside the mountain, can open or shut in just 45 seconds. Hardened microwave channels and coaxial cables provide essential communications links for the state-of-the-art electronic and computer systems inside the facility.[6] (See Illustration 50 for schematic diagrams of how these communication links might look.)

NORAD AT NORTH BAY, ONTARIO, CANADA - This deep underground command center, which is located about 200 miles north of Toronto, is also jointly staffed by both Canadian and U.S. military personnel. The North Bay installation became operational in October 1963 and consists of two huge caverns, bored out of the solid rock, hundreds of feet under the Pre-Cambrian Shield. The two huge caverns, each 400 ft. long, by 60 to 70 ft. high and 45 ft. wide, are connected by three cross tunnels. Inside the caverns, just as at Colorado Springs, three-story buildings have been constructed to house personnel and equipment. There are two access tunnels, the one about 6,600 ft. long and 12 ft. by 12 ft., the other about 3,500 ft. in length and 16 ft. by 16 ft. Inside are 142,000 sq ft. of floor space, filled with offices, communications and computer equipment, and defense radars that cover the northern

sectors of North American air space.

There are also kitchen and dining facilities that can accomodate 400 people, a hospital and infirmary, washrooms and showers, a "well equipped canteen," and space for people to rest and sleep. Power is supplied by six generators that are normally fueled by natural gas piped down from the surface. Under emergency conditions the generators would run off of diesel fuel stored underground in the complex. During normal operations, water for equipment cooling and personnel use is obtained from nearby Trout Lake. But during emergency "button-up" conditions water would come from underground reservoirs specially excavated for use when the facility was sealed off from the outside. One reservoir holds 200,000 gallons for domestic use, and the other contains five million gallons for air conditioning and equipment cooling.[7]

Federal Emergency Management Agency (FEMA)

There are other secret underground government command facilities. Many of them are operated by FEMA, the Federal Emergency Management Agency. FEMA usually pops up in the news as the lead federal agency charged with hurricane or flood relief efforts. But FEMA has another side as well -- a secret, underground side.

MOUNT WEATHER, BLUEMONT, VIRGINIA -- The hub of the FEMA subterranean network is located inside Mount Weather, near the small town of Bluemont, in northern Virginia. This top-secret base was constructed in the 1950s to house the United States government in the event of a national crisis such as nuclear war. Funded by "black" money, Mount Weather remains nearly as inaccessible to scrutiny as it was when first built. Although it is the headquarters for FEMA's far-flung underground empire it

does not even appear in the agency's published budget. Security is tight at the installation, which is surrounded by a 10-ft. perimeter fence patrolled by armed guards. There are a few buildings above ground, but most of the real work of Mt. Weather takes place deep below, in great secrecy. The mountain contains what amounts to a small town. The infrastructure includes: a small lake; a pair of 250,000 gallon water tanks, capable of supplying water for 200 people for over a month; a number of ponds 10 ft. deep and 200 ft. across, blasted out of solid rock; a sewage plant capable of treating 90,000 gallons per day; a hospital; a cafeteria; streets and sidewalks; a diesel powered electrical generating plant; private living quarters and dormitories able to accomodate hundreds of residents; a sophisticated, internal communications system using closed-circuit color TV consoles; a radio and TV studio; massive super-computing facilities; a "situation room" equipped with communications links to the White House and "Site R" in southern Pennsylvania; and a transit system of electric cars that transport personnel around the complex. According to published reports, some of the hundreds of people who work inside the mountain routinely stage practice drills for managing a wide variety of potential crises, ranging from civil disturbances and economic problems, to natural disasters and nuclear war.[8]

Speaking off the record, in the mid-1970s government officials stated that, in fact, Mt. Weather houses a resident, back-up government. Many federal departments and agencies are represented there, including the Departments of Agriculture, Commerce, HUD, Interior, Labor, State, Transportation and the Treasury; and agencies such as FEMA, the Office of the President, the U.S. Postal Service, the Federal Communications Commission, the Federal Reserve, Selective Service, the Federal Power Commission,

the Civil Service Commission and others. These highly placed government sources maintain that the administrators of the Federal departments at Mt. Weather hold cabinet-level rank and are referred to as "Mr. Secretary" by the personnel who work under them. These covert "Secretaries" are said to keep their positions over the course of more than one administration, their terms not being limited by the presidential election cycles that govern the terms of office of their Washington counterparts.[9] These are sensational allegations, but if they are true, then the political news we are fed in the mainstream media must be fictional to some, unknown degree and the system governing us is controlled to that same unknown degree by agencies and officials who work in great secrecy, literally underground and totally unaccountable to the citizenry of the United States.

Mount Weather serves as a hub for a system of other underground installations and bunkers, known as Federal Relocation Centers. These are located within a 300 mile radius of Washington, DC known as the "Federal Arc." Key government officials and personnel would be evacuated to these centers in the event of nuclear war as part of the Continuity of Government (COG) plan. Besides Mt. Weather, there are said to be an additional 96 of these centers in Pennsylvania, Maryland, West Virginia, Virginia and North Carolina.[10]

Presumably, at least some of the approximately 50 secret, underground command posts mentioned earlier in the discussion of military facilities would be among these 96 centers in the FEMA Continuity of Government system. Among other things, the centers are said to contain data files and computer systems maintained by a variety of Federal agencies, and are supervised by the facility at Mount Weather.[11]

A 1991 Jack Anderson column in The Washington Post reported that the COG system was created by the Reagan administration and consists of a "$5 billion network of bunkers filled with high-tech communications equipment at secret locations around the country."[12] Just how many of these secret centers were newly constructed during the 1980s, and how many are older facilities that the Reagan adminstration merely converted to its purposes (expanded, remodeled and modernized) is not known. My guess is that at least some of the dozens of secret COG facilities are mentioned in this book. Of course, that would leave dozens of others which are not.

MOUNT PONY, CULPEPER, VIRGINIA -- There are several underground installations either known, or alleged, to exist in the five-state "Federal Arc" area. The best known is probably the large bunker complex that lies under Mount Pony, a couple of miles east of Culpeper, Virginia, just off of Rt. 3 in the northern part of the state. Although one published report identifies this underground facility as the emergency relocation center for the Treasury Department,[13] two other reports,[14] local rumor and the sign by the front gate identify the installation as a "Federal Reserve Center." Constructed in the late 1960s, the 140,000 sq ft. facility is said to be supplied with water, food, a generator, communications equipment and even cold-storage for corpses. One source who formerly worked in the Culpeper area told me it is believed that the Federal Reserve stockpiles very large supplies of United States currency there. Indeed, 5 billion dollars are reportedly stored under Mt. Pony.

But this is not a dormant facility, waiting for Armaggedon before springing to life. From its underground vantage point in Culpeper the Federal Reserve constantly monitors all major financial transactions in the United

States. It does this by means of the "Fed Wire," a modern, electronic system that permits it to keep track of all major business and banking activity that occurs.[15] Why does the Federal Reserve need a secure, underground bunker to monitor the nation's economic life? I don't pretend to know, but clearly, judging by the intermittent traffic going in and out the front gate on the day I visited, the Mount Pony bunker is in active use and doing something.

As it happens, just six weeks after my mid-June 1992 visit to the Federal Reserve's Mount Pony bunker a cover story appeared in Time Magazine that dealt, in part, with that very installation. The story said that, as of July 1992 "the facility's mission will no longer be needed."[16] My opinion is that this may well be disinformation. I doubt very much that the Federal Reserve has really abandoned its bunker in Culpeper. And even if the bunker really were to be emptied out, my suspicion is that the contents would merely be transferred to another, more secure location, quite likely also underground.

For what it is worth, I had spoken on the phone with the Time Magazine article's author just a few days after visiting the Mount Pony bunker. He wanted to know where I found my information about underground bunkers and installations, and so I mentioned a few of the installations to him that I knew about at that time.

FEMA IN OLNEY, MARYLAND -- Another, less well known, underground installation is located on Riggs Road, off of Rt. 108, between Olney and Laytonsville, MD. Although it has been reported that there are actually two such facilities, a Federal Emergency Management Agency (FEMA) civil defense bunker in Olney and a bunker operated by an unknown government agency in Laytonsville,[17] a recent visit to the area turned up only one site, midway between the two towns. If there is another

bunker in the vicinity it is sufficiently well concealed that it is hard to spot. While it is not clear to passers-by who operates the facility on Riggs Road, since there are only generic United States government "NO TRESPASSING" signs posted on the security fence that surrounds the complex, this site is reportedly the backup command center for FEMA's day-to-day operations.[18] When I arrived the gate was open and no one was in the guard house. However, a prominently placed sign did advise that the entrance area was under electronic surveillance. So presumably, any unauthorized intrusion would not go unchallenged.

The one building visible from outside the fence is in an advanced state of disrepair and gives every appearance of having been vacant for some years. However, the real work at this site takes place beneath the surface. One former Maryland resident who told me of the site spoke of seeing a long line of cars heading through the gate when shifts change and disappearing behind a slight rise in the near distance. I did speak with one man who had been inside the place many years ago on a school field trip. He remembers going down two or three levels and seeing an underground office complex and electronics facilities. This is not surprising given the large number and variety of aerials and antennae visible on the surface. Both this man and another local with whom I spoke said that the bunker is believed to extend as deep as ten levels underground.

THE GREENBRIAR HOTEL, WHITE SULPHUR SPRINGS, WEST VIRGINIA — Recent revelations about a large, secret bunker beneath the posh Greenbriar Hotel in White Sulphur Springs, West Virginia make clear that it is entirely possible to keep the existence of a large, underground installation out of the public eye for decades on end. Until the story broke in the last week of May 1992 only six members of Congress knew that between 1958 and 1961 a warren of

living quarters, meeting rooms, and banks of computers and communications equipment had been installed underground beneath the hotel, located about 250 miles southwest of Washington, DC in the Allegheny mountains. Situated behind two giant blast doors, each weighing more than 20 tons, and supplied with water, electricity and sewage treatment, the complex is large enough to house eight hundred people. It contains a large dormitory; an infirmary; shower facilities; a television studio; radio and communications equipment; phone booths and code machines; a dining and kitchen area; a power plant; and even a crematorium for getting rid of the corpses of those who might die inside the sealed bunker. According to published reports, the bunker was constructed to shelter the United States Congress in the event of a nuclear attack.[19]

Of course, the obvious question is: in the certain chaos of an impending nuclear war how could the hundreds of members of Congress take shelter in a distant bunker that most of them did not even know existed? According to press reports, only a few local people, the hotel management and maintenance staff, a handful of government officials, and other government personnel with a "need-to-know" appear to have been aware of the installation. Could it be that the bunker has, or had, another purpose which is not being divulged? After all, if the bunker itself was kept secret for over 30 years isn't it conceivable that there is more to the story than has so far been publicly admitted?

FEDERAL REGIONAL CENTERS - In addition to the huge bunker at Mt. Weather and bunkers in the neighboring states, FEMA also operates underground installations at other sites around the country. Reported locations for these facilities, designated as Federal Regional Centers, are:

Santa Rosa, California; Denver, Colorado; Thomasville, Georgia; Maynard, Massachusetts; Battle Creek, Michigan; Denton, Texas; and Bothell, Washington.[20] There are probably others; these are the ones that can be identified from the public record.

I did file a Freedom of Information Act (FOIA) request with FEMA asking where their underground facilities were located. Even though information about underground FEMA sites is readily available in the public domain, FEMA refused to name them, citing national security provisions of Executive Order 12356, although they did list the following FEMA facilities in a letter to me:[21]

FEMA Headquarters	Washington, DC
FEMA Special Facility	Round Hill, VA
National Emergency Training	Emmitsburg, MD
Software Engineering Division	Charlottesville, VA
National Warning Center*	Cheyenne Mountain Colorado
FEMA Regional Offices (RO)	
Federal Regional Centers	
Region I	Boston, MA (RO) Maynard, MA (FRC)
Region II	New York, NY (RO)
Region III	Philadelphia, PA (RO) Olney, MD (FRC)
Region IV	Atlanta, GA (RO) Thomasville, GA (FRC)
Region V	Chicago, IL (RO) Battle Creek, MI (FRC)
Region VI	Denton, TX (RO/FRC)

* This is a FEMA presence at a Dept. of Defense facility. Information about that facility would be kept by DOD.

Region VII	Kansas City, MO (RO)
Region VIII	Denver, CO (RO/FRC)
Region IX	Presidio, CA (RO)
Region X	Bothell, WA (RO/FRC)

Communications Antenna Fields	Fort Custer, MI
	Santa Rosa, CA
Strategic Storage Centers (for Disaster Assistance)	
Blue Grass	Richmond, KY
Forest Park	Forest Park, GA
Dempsey	Palo Alto, TX

The observant reader will note that I have already identified 10 of the facilities listed above as underground FEMA installations.

I do not know if any of the other facilities listed in the FEMA response to my request include an underground component. My guess is that some, or all of them, well may. I welcome information from readers who can tell me more.

The Defense Nuclear Agency

In 1975 the Defense Nuclear Agency published a detailed, geological study that discussed dozens of possible sites all over the country for very deeply based military installations - as much as 5,000 ft. underground.[22] Some of these prospective sites are relatively large in area, while others are fairly limited in geographic extent. Most of them are in the West; a few are located in the mid-West and on the Eastern Seaboard. The report delineated the sites as follows:

East

Adirondack Mountains, New York (in vicinity of Elizabethtown)

3 sites in Central New Hampshire

Area to northwest of Portland, Maine

Northeastern, Central and South Central Virginia

Mid-West

St. Francois Mountains, Missouri (between St. Louis and New Madrid)

Northern Wisconsin (general area between Chippewa Falls, Wausau and Florence)

Minnesota River Valley (generally 30-40 miles south of Benson and about 50 miles southwest of Minneapolis-St. Paul)

West

Southeastern Wyoming

Rio Grande River Valley, New Mexico (to west and north of Taos; area of special interest 20-30 miles north of Taos, near Colorado border)

Pedernal Hills, New Mexico (60-70 miles east-southeast of Albuquerque)

Zuni Mountains, New Mexico (100 miles due west of Albuquerque, south of 1-40)

La Sal Mountains, Utah (20 miles southeast of Moab)

Sierra Nevada Mountains, California (large area 350 miles long by 50 miles wide)

Idaho Batholith (large area in central Idaho, north of Boise)

South Central Idaho (under Snake River lava flows between Twin Falls and Idaho Falls)

Holbrook, Arizona (general vicinity)

Northwestern Arizona (north of Seligman)

Ash Fork and Williams, Arizona (general vicinity)

Black Mesa Basin, Arizona (under Hopi and Navajo

Reservations)

Book Cliffs-Uncompahgre Uplift. Area along Utah-Colorado border (in general vicinity of and to south of Grand Junction, Colorado)

Monument Uplift and Blanding Basin, Utah (southeastern part of state near towns of Blanding and Mexican Hat)

San Rafael Swell, Utah (west of town of Green River)

Extreme West Central Utah (area 30-40 miles west of towns of Delta and Minersville)

Southwestern Utah (area between towns of Cedar City and Panguitch)

Nuclear Test Site, southern Nevada

Central Nevada (50 mile radius of town of Tonopah)

Northwestern Nevada (50 to 100 miles east and northeast of Carson City)

Special Sites

Washington, D.C. (surrounding area in Virginia and Maryland)

Omaha, Nebraska (general vicinity)

Readers should bear in mind that any installations that may have been built in these areas are likely to be well hidden, and very deeply buried. In addition, since the areas are often rather large, the directions provided are of necessity only a general guide to the location of possible installations. After all, the geological formations of interest to the Pentagon for subterranean bases usually extend for miles. Also, entrances to underground facilities may be some distance away from the base itself. So finding these places is not necessarily an easy task.

My guess is that some of these sites have been used for underground base construction over the last 20 years. Readers who may have information about the presence of

underground bases at any of these sites are urged to get in contact with me.

Deep "Black" Underground: The Oliver North Connection

In Oliver North's autobiography, Under Fire, he briefly mentions an extremely secret government program called "The Project." According to North, for a year and a half during Reagan's first term he was the "de facto administrator of The Project" and coordinated a group of expert advisors known as the "Wise Men." The work of the Wise Men and The Project entailed providing for the survival of the United States government in the event of a nuclear war. North specifically says that he wrote policy directives pertaining to The Project which President Reagan signed, and that he also often briefed then Vice-President George Bush about The Project. While North does not say precisely how The Project was carried out he does mention that the Soviet Union had "a network of secret tunnels under Moscow" to which its leaders would flee in time of war, while the United States had nothing comparable.[23] By implication, then, The Project would seem to have provided a similar capability for the United States.

In fact, it seems that The Project did involve an extensive underground construction program. In April 1994 a front page story in the New York Times announced the existence of a previously undisclosed program known as "The Doomsday Project." According to the story, the project was an "amalgam of more than 20 "black programs" during the Reagan administration, supervised by George Bush, with some involvement by Oliver North. It reportedly cost some $8 billion to build and took eleven years to complete. The Doomsday Project was concerned with the

survival of the federal government in the event of nuclear war. The project involved many people, including "White House officials, Army generals, CIA officers and private companies." Of direct interest for readers of this book is the fact that the Pentagon built "scores of secret bunkers" as part of something called the "Presidential Survivability Support System."[24] It is my educated guess that many of these "secret bunkers" would be located in the areas and locations set forth in previously discussed documents generated by the Army Corps of Engineers, U.S. Air Force Project RAND and the Defense Nuclear Agency.

Last But Not Least: Underground Command Center For Sale

And finally, this throught-provoking footnote to our tour of underground strategic command centers: As of 1992 there was a decommissioned Strategic Air Command bunker for sale in Amherst, Massachusetts. The 44,000 sq ft. bunker is three stories high, buried under a mountain, blast-proof, climate-controlled, with a glassed-in command theater. It was for sale for just $250,000.[25] There are a couple of interesting things about this piece of information. First, the size and location of this bunker underscore the fact that underground facilities and installations can literally be almost anywhere. Second, the fact that SAC is getting rid of it on the open real estate market means that it must be obsolete. So obsolete that they don't care who goes inside, and they don't care who knows where it is.

One obvious conclusion would be that the Pentagon now has something better, somewhere else.

Chapter Four

MORE UNDERGROUND FACILITIES: MILITARY, GOVERNMENT, NUCLEAR AND BUSINESS

Although I've been told that the Pentagon operates many other underground facilities here in the United States, perhaps dozens more than I've discussed so far, in this chapter, as in the previous chapter, I will err on the conservative side and report only on those underground installations for which I can provide some form of tangible documentation.

Along with military installations I also report on facilities run by other branches of the government, and on some run by private business. Currently, I can positively verify just seven underground corporate facilities. I strongly suspect there are many more. I welcome information in that regard from readers who know of other underground corporate facilities.

But whether it's the Navy or the Federal Reserve or private industry, they all seem to have one thing foremost in their minds: S-E-C-R-E-C-Y.

ATCHISON, KANSAS -- At Atchison, Kansas the Pentagon operates (or used to operate) the Defense Industrial Plant Equipment Facility (DIPEF). This huge underground warehouse facility, with 987,000 total square ft. of space, is a converted and remodeled limestone mine. The facility is serviced by underground roadways that make it easy to

move the thousands of items of machine tools and industrial equipment stockpiled there. Half of the underground area is paved with concrete and the entire facility is climate controlled. As of 1974 138 people were employed at the DIPEF.[1]

THE FEDERAL RESERVE -- A 1981 Wall Street Journal article says that, "Nine of the 12 Federal Reserve Banks have underground emergency quarters, where records are updated daily." I do not know where most of these underground emergency centers are, or how elaborate they are. Neither do I know exactly what kind of records are kept in them. However, since the Federal Reserve is the agency that controls national monetary policy I would speculate that the records it keeps in these underground centers might well have to do with the national money supply and the daily affairs of the world of high finance. Moreover, since we are living in a computerized, electronic era of instantaneous telecommunication I would speculate further that these underground centers might contain sophisticated computing and communications systems. But all this is speculation on my part, since I have never been in the Federal Reserve's underground facilities.[2]

NATIONAL SECURITY AGENCY, FT. MEADE, MARYLAND -- Beneath the National Security Agency's headquarters at Fort Meade, Maryland are "cavernous subterranean expanses," said to be filled with more than ten acres of the most sophisticated supercomputers that money can buy.[3] The NSA operates in tremendous secrecy; however, it is a safe bet based on what is known about the agency that these computers are engaged in a massive surveillance of much of the world's telephone, telegraph, telex, fax, radio, TV and microwave communications, including surveillance of domestic, internal U.S. communications by ordinary citizens. In a word, Big Brother is already here, and his

name is "NSA."

THE DEPARTMENT OF ENERGY'S NEVADA TUNNELS AND INSTALLATIONS — The DOE also has many underground tunnels and installations in Nevada. Most of the DOE activity appears to be conducted at the Nevada Test Site (NTS), where the Department of Defense (DOD) and the DOE have for decades been excavating tunnel complexes for underground testing of nuclear weapons (See Illustrations 13 and 14).

These tunnel networks can be quite elaborate (See Illustration 15). The DOE and DOD sometimes reuse the tunnels; other times they are apparently abandoned. Their usual practice is to pack the tunnels with all sorts of sophisticated, hi-tech equipment and machinery to monitor the blasts (See Illustrations 16 and 17). Much of the monitoring takes place within thousandths of a second, even millionths of a second after the nuclear device detonates.

I do not know the purpose of all of the hundreds of underground nuclear blasts (a number that seems excessively high) detonated by the DOD and the DOE; I only know that there have been many, many of them and that there are many tunnels under the nuclear test site. I do not know where all of the tunnels are, what they are all used for, or how extensive the interconnections between them are, providing such interconnections exist at all.

Like many students of UFOlogy I have heard rumors and read anecdotal accounts that allege there are extensive underground complexes for living and working under the Nevada Test Site. I am inclined to think some of these accounts may be true, but I cannot provide factual documentation that demonstrates that such facilities exist.

The DOE also operated a test facility at the NTS in the

early 1980s, deep underground, for storing nuclear waste (See Illustration 18).

THE NUCLEAR WASTE DEPOSITORY AT YUCCA MOUNTAIN,
NEVADA — Evidently the nuclear waste storage tests in the early 1980s were successful, or at least encouraging, because in 1991 and 1992 the DOE actively solicited companies for construction of a deep underground tunnel complex inside and beneath Yucca Mountain, about 100 miles northwest of Las Vegas, as another "test" depository for nuclear waste. The actual name of the facility is the "Yucca Mountain Site Characterization Project, Exploratory Studies Facility (ESF)." The solicitations were for companies that can provide: tunnel boring machines (TBMs) capable of boring tunnels of 25 ft. to 30 ft. in diameter; mobile miners and other mining equipment for excavating tunnels; conveyors and muck removal systems; underground ventilation, water and power supply systems; and all requisite support facilities, buildings, roads and equipment for excavating and maintaining a major, underground complex. Construction was slated to begin in November 1992. Reynolds Electrical & Engineering Co., Inc., which is the Prime Management and Operations Contractor for the Nevada Operations Office of the Department of Energy, is the company that will supervise construction and carry out the actual testing at the facility when it is constructed.

The plans call for 14 miles of underground tunnels and ramps, ranging from 14 ft. to 25 ft. in diameter, with grades as steep as -16%. Since the facility also is slated to contain a 1,300 ft. vertical shaft, by implication the complex will be at least 1,300 ft. beneath the surface.

Here again, as with so much of what goes on underground, it is hard to say what the DOE is up to. Maybe they really are making a test facility for long-term

storage (10,000 years) of nuclear waste. Or maybe the high-security curtain of the Nevada Test Site provides a convenient screen behind which the DOE can carry out other, more secret projects, under the public relations rubric of a nuclear waste "test" facility. The trail of lies at the DOE, and at its predecessor, the Atomic Energy Commission (AEC), is so long where things nuclear are concerned it is hard to know when to trust the public relations rhetoric and press releases. The more so, since no one without a security clearance (people like the author of this book, for instance) is usually allowed anywhere near these facilities, let alone permitted to actually go underground to poke around to see what is there.[4]

LOS ALAMOS, NEW MEXICO -- At a June 1983 scientific conference in Lake Tahoe, the Los Alamos National Laboratory (which is located in northern New Mexico, but run by the University of California) put forward a proposal for a "National Underground Science Facility" to be constructed deep beneath the Nuclear Test Site in southern Nevada. The proposal called for the facility to be built 3,500 ft. underground, with the possibility of extending it as deep as 6,000 ft. Initially, Los Alamos envisioned two experimental test chambers for doing particle physics, gravity experiments and geophysical studies. The facility would also include machine and electronic shops, a small computer, and dormitory space.[5] Whether or not this installation was built I do not know. But, even if it wasn't, the fact that a government agency was actively planning to go as far down as 6,000 ft. to construct a manned scientific facility gives an idea of how deeply based these underground installations can be. Most of the underground facilities I identify in this book range anywhere from tens to hundreds of feet underground. However, it is quite possible that there are bases that are thousands of feet

underground. Researchers and students of this subject should be prepared to think of bases located as much as a mile or more beneath the surface. That may seem implausibly deep, but I promise the reader that at the Pentagon there are planners who have commissioned studies calling for military bases to be built as deep underground as 8,000 feet below the surface of the earth -- that's over a mile and a half down! Those plans are discussed later in this book.

STANDARD OIL CO. OF NEW JERSEY -- As recently as 1970 Standard Oil Co. of New Jersey operated an emergency center 300 ft. underground in upstate New York, near Hudson. The facility was formerly known as Iron Mountain Atomic Storage. The site contained company records, "vaults, dining halls and more than 50 sleeping rooms for key company officials and their families." [6] More recent reports indicate this facility is now used for storage of corporate records.

NORTHROP - In the Antelope Valley of southern California, near the towns of Rosamond, Palmdale and Lancaster are three mysterious underground facilities, operated by Northrop, Lockheed and McDonnell Douglas. (See Illustration 19). The Northrop facility is located near the Tehachapi Mountains, 25 miles to the northwest of Lancaster. There are rumors that the installation there goes down as many as 42 levels, and that there are tunnels linking it with other underground facilities in the area. I do not know whether these rumors are true or not. There are also reports of many strange flying objects in the vicinity, of many shapes and sizes. Some are reportedly spherical, others are alleged to be triangular, elongated, boomerang or disk shaped. And they are said to range in size up to hundreds of feet in diameter. The facility itself is engaged in electronic or electromagnetic research of some sort. There are large radar or microwave dishes and strange-

looking pylons to which various objects can be affixed, ostensibly for the purpose of beaming electromagnetic radiation at them. These pylons rise up from underground out of diamond-shaped openings in the middle of long, paved surfaces that resemble aircraft runways, but which, in fact, are not used by aircraft.

MCDONNELL DOUGLAS -- The McDonnell Douglas facility is located at the now closed Gray Butte airport, northeast of Llano, California. It too has "runways" that are not runways, with diamond-shaped openings through which huge pylons with strangely shaped objects mounted on them are raised to the surface. These objects sometimes resemble elongated disks or flying saucers and have been seen to glow and change colors. Glowing spheres have also been seen by people in the area at night. However, the nature and function of the spheres is not known.

LOCKHEED -- The Lockheed installation is adjacent to what used to be the Hellendale auxiliary airport, six miles to the north of Hellendale, California. Just like the McDonnell Douglas and Northrop facilities it also has the runway-like features, with large, diamond-shaped doors through which huge pylons rise from underground with strange objects attached. This facility also has an obvious underground entrance. (See Illustrations 20 and 21.)

To compound the high strangeness of these California facilities, there are ominous reports of covert military activity associated with them, possible alien activity (and I emphasize possible), possible abductions and lost time episodes, and numerous sightings of extremely unconventional aircraft and flying objects, to which I have already alluded.[7]

AMERICAN TELEPHONE & TELEGRAPH - A 1981 report revealed that AT&T had seven "emergency centers" in separate regions of the country. At least three of these

were underground complexes. Near Netcong, New Jersey, to the west of New York City, AT&T buried a three-story emergency center in the granite, 40 ft. below ground. In the center were "...executive living quarters, a control room and a computer (with) the data bank for AT&Ts entire system." Also in the center were a "kitchen, a month's supply of food for 100 people, sleeping quarters and emergency generators." Facilities like the one at Netcong were also located at Rockdale, Georgia and Fairview, Kansas.[8] And I have been told there are others all over the country, in isolated rural areas. One of these underground AT&T communications facilities is said to be located in Catron County, New Mexico.[9]

In the preceding pages I have set out dozens of known underground facilities, installations and bases. Some of these are quite complex and sophisticated installations, capable of supporting large numbers of people in some degree of comfort. Some are operated by the military, or other branches of government, and some are run by Fortune 500 companies in the military-industrial complex. I have also presented information on dozens of other possible sites where the military was contemplating building deep underground installations.

By now it should be clear that underground bases and installations could literally be just about anywhere: under a military base; under a major hotel; under a prominent government building; under old, abandoned mine workings; under virtually any mountain or hill; under a national park, or perhaps in a national forest; in a small town; or in the middle of a large city - maybe even deep under an Alaskan glacier. And as the Army Corps of Engineers documents spell out, these underground facilities could be - and in many cases probably are - well

camouflaged and concealed, making detection by a casual observer difficult.

The purpose and function of many of these facilities appear to be related to either the waging or the surviving of nuclear war -- or both. Of course, many other agendas and projects could conceivably be carried out in these underground installations as well. Let your mind run — secret scientific research? Super-secure prisons where people are secretly detained incommunicado? Extraterrestrial living areas?

I must confess that while I don't have many answers, at the least it does seem certain that the southern California Lockeed, Northrop and McDonnell Douglas facilities mentioned above are heavily engaged in nonconventional, hi-tech aerospace research. And while there are stories floating around in UFO circles about bizarre, Nazi-style genetic engineering programs being conducted in underground facilities by "Little Grey" aliens and the U.S. military I can offer no proof that such programs exist. They may exist; they equally may not.

As for the possibility of secret, underground prisons: I will simply observe that many people absolutely disappear in this country every year, never to be heard from again. No bodies are found, no trace of them ever surfaces. I don't know where these people go; I don't know what happens to them. I can offer no proof that any of them are held in secret underground prisons. I cannot even offer any proof that there are secret, underground prisons. However, it occurs to me that at the end of WW II many German citizens were surprised to find out that there were concentration camps, run by the Nazis, in which millions of their neighbors (Jews, Gentiles, Gypsies, mentally impaired, homosexuals, political prisoners) had been incarcerated, tortured, forced into slave labor - and killed.

Given the many underground facilities secretly operated by the U.S. government, could a similar, smaller-scale program be going on here? I have no proof of such a program, but considering the large numbers of disappeared people and the existence of dozens of underground installations operating behind a thick security veil it occurs to me that the possibility is at least conceivable.

As I have shown, there is every reason to think that the underground construction plans and activities of the military continued during the 1970s, 1980s and into the 1990s.

A 1974 report by Bechtel Corporation, a huge multi-national company that derives significant revenues from government contract work, stated that, "The demand for tunneling and underground excavation for national defense needs is believed to be large. Some examples of underground defense facilities include: hard-rock silos, command posts, communications systems, personnel shelters, storage and power generation facilities."[10]

And a 1981 report issued by the U.S. National Committee on Tunneling Technology made a similar point: "The demand for defense-related underground construction will be affected significantly by decisions made in the early 1980s. It could be for as much as 20 million cubic meters for missile sites and underground command posts, most of which would be constructed between 1985 and 1995. These projects do not include the civil construction routinely carried out by the (Army) Corps of Engineers."[11]

In other words, there could easily be a lot of covert construction going on beneath our feet right now.

Chapter Five

THE MOTHER OF ALL UNDERGROUND TUNNELS?

In UFOlogy, stories of secret, deep-underground tunnel systems, and the hi-tech tunnel boring machines that make them, are often heard in connection with sensational stories of secret, underground bases that are jointly "manned" (is that the right word?) by those pesky aliens known as the "Little Greys" and covert elements of the military-industrial complex. I don't know whether the Little Greys are real or not. Nor do I know whether the alleged tunnel systems are real or not.

But, I do know that the United States military had extensive plans in the 1980s to construct a very deep, hundreds-of-miles-long, underground tunnel system somewhere in the western United States.

And in 1968 The Office of High Speed Ground Transportation of the United States Department of Transportation (DOT) drew up plans for a very deep underground tunnel system in the Northeast. This system was to have run between Washington, DC and Boston, Massachusetts. This chapter explores both the military and the DOT tunnel system plans.

Before presenting the documentation on these projects, I'd like to say that I don't reject out of hand the possibility of secret, underground tunnel systems. Far from it. In fact, based on much research and many conversations, I think there may very easily be secret tunnel

systems, deep underground, that may be quite lengthy. But since I cannot rigorously document their existence, I will restrict the discussion to a presentation of what can be documented — U.S. government plans for deep underground, elaborate tunnel systems.

U.S. National Committee on Tunneling Technology - and Pentagon Plans for a Deeply Based Missile Tunnel System

In 1972 the Chairman of the Federal Council for Science and Technology asked the Presidents of the National Academy of Sciences and the National Academy of Engineering to establish a U.S. National Committee on Tunneling Technology (USNC/TT). The committee was then formed by the Governing Board of the National Research Council.

The committee functions as the "United States focal agency in the field of tunneling technology, to assess and stimulate improvements in tunneling technology applications, and to coordinate U.S. tunneling technology activities with those of other nations." Its members are drawn from a wide variety of federal, state and local government agencies; from academic departments in universities; and from private industry, labor organizations and consulting firms. In 1977 the USNC/TT had the following subcommittees:

a) Management of Major Underground Construction Projects
b) Deep Cavity and Tunnel Support Systems
c) On Site Investigation
d) Demand Forecasting
e) Education and Training
f) Contracting Practices[1]

Deep Underground Tunnel Plans

In 1981 and 1982 the USNC/TT sponsored a special project called "Workshop on Technology for the Design and Construction of Deep Underground Defense Facilities."[2] The project was sponsored by the U.S. Bureau of Mines under contract no. JO 199025. Co-sponsoring agencies with the Bureau of Mines were the U.S. Geological Survey, Bureau of Reclamation, Defense Nuclear Agency, Department of the Air Force, Department of the Army, Department of the Navy, Department of Energy, National Science Foundation, Federal Highway Administration and the Urban Mass Transportation Administration. The workshop was called at the request of the Defense Nuclear Agency to plan for the construction of a deeply based nuclear missile system. The moderator of the workshop was Edward J. Cording, of the Department of Civil Engineering, University of Illinois at Urbana and then chairman of the USNC/TT. Work groups were formed for Siting; The Use of Existing Underground Space; Egress; Mechanical Mining; Construction Planning; and Management, Contracting, Costing, and Personnel. The select roster of participants included dozens of professionals, including private consultants and consulting firms from many states; public utilities such as Pacific Gas & Electric Co.; universities such as Cornell, Stanford, Pennsylvania State and the Colorado School of Mines; and even a union (Local 147 of the Compressed Air and Free Air Tunnel Workers).

According to reports issued by the USNC/TT in 1982, the planners assumed that 400 miles of tunnels ranging from 2,500 to 3,500 ft. underground would need to be constructed to connect the deep bases that would house MX nuclear missiles. The tunnels would be 16 ft. in diameter, "with access shafts, interconnecting passageways,

and adits for storage, living quarters and other needs." (An adit is either a horizontal passageway, an entrance, or an approach).

Electric power would be obtained from either fuel cells or nuclear reactors. Spare tunnel boring machines would also be stored in the tunnel sytem. The plan mentioned deep underground shops for the complete repair of tunnel boring machines. There were to be special tunnel boring machines for digging out from deep underground after a nuclear attack, so that reserve nuclear missiles stored thousands of feet underground could be fired in retaliation.

In the event of war, the base would be sealed off and power for the underground system of tunnels, tunnel boring machine repair shops, crew quarters and missile nests would need to be internally generated. Boeing Aerospace Company published the results of a study in 1984 that set forth plans for power generation in a sealed, deep ICBM base.

After examining several options, Boeing decided that iron-chlorine fuel cells would be the most efficient way to generate electricity. In this power-generation scheme huge, underground tanks store liquid chlorine that is combined with hydrogen to form hydrochloric acid (HCL). This chemical reaction generates electricity. The HCL is then pumped into huge tanks filled with small iron balls; the iron (Fe) and HCL react chemically to form ferrous chloride ($FeCl_2$) and release hydrogen gas, which is then pumped back to the fuel cell to react again with the liquid chlorine, starting the whole cycle over. Iron-chlorine fuel cells are the preferred mode of power generation if the post-attack confinement of the base lasts for less than four years.

If the base were to be sealed for more than four years, however, financial cost-benefit analysis indicated that

liquid-metal-cooled nuclear reactors would be recommended over iron-chlorine fuel cells. The report does not say, but based on other literature I have seen the liquid-metal used to cool the liquid-metal-cooled reactors would probably be lithium.[3]

The USNC/TT tunnel plan called for the system to be built in the late 1980s and early 1990s, with "mobilization" of manpower and resources beginning in the early 1980s. The probable tunnel boring machine (TBM) supplier for the project indicated that it could supply "two machines between January and June 1985, one machine per month between July and December 1985, two machines per month between January and June 1986, and three to four machines per month thereafter." That supply schedule was predicated on using a 16 ft. tunnel diameter. If 18 ft. were selected as the diameter, the manufacturer was able to make available 8 to 10 second-hand TBMs that could be reconditioned for immediate service.[4]

The report includes artists' conceptions of how portions of a deeply based missile tunnel system might look (See Illustrations 22-24). Where might this system be located, assuming it has already been built, or is now under construction?

The planners assumed it would be built somewhere in the western third of the country (See Illustration 27). Three specific sites mentioned in the text of the report are (a) Forty-Mile Canyon in Nevada; (b) Grand Mesa, Colorado; and (c) the basalt plain in the Columbia River Basin, near Fairchild Air Force Base in the State of Washington.

There are other federal documents and press reports which explicitly discuss this deep underground tunnel system. In August 1980, the Air Force released a detailed, two-volume study which was prepared by the School of

Mines, in Golden, Colorado. The study is entitled, "Tunnel Boring Machine Technology for a Deeply Based Missile System."[5] It calls for a 480 km long (about 300 miles), deep underground tunnel system that would connect "missile nests" 2400 ft. or more underground. In the event of nuclear war, the plans call for military crews to operate mechanical, tunnel boring machines that would bore up to the surface from bases half a mile or more underground, towing nuclear missiles behind them, which they would then fire at the enemy (See Illustrations 25 and 26 for schematic diagrams of the egress tunnel boring machine designs, and missile egress plans from deep underground). The tunnel boring machine companies mentioned in the report are The Robbins Company, of Kent, Washington and Jarva Inc., of Solon, Ohio. Morrison Knudsen, of Boise, Idaho (a huge company with subsidiaries in many states) is mentioned as a construction consultant.

There are many other documents and articles that detail these plans. In 1984 The New York Times ran a front page story that described the planned, underground missile base as something like a "400-mile network of subways that would be 2,500 to 3,500 feet below the surface, probably in a desert in the western United States."[6] In 1985 the Asian Defence Journal ran an almost identical story.[7]

A highly technical 1985 document from the Air Force Geophysics Laboratory discusses ground motion effects that a deep underground facility might experience were it to undergo nuclear attack. In particular, it refers to an "underground missile base within Generic Mountain B in the ICBM Basing Construction Planning Study."[8] Unfortunately, no specific location or layout for the missile base is mentioned.

A 1985 report from the Army Corps of Engineers Omaha District explicitly refers to an "ICBM deep basing

construction planning study." [9] Another, 1988 report by the U.S. National Committee on Tunneling Technology and the U.S. National Committee for Rock Mechanics discussed an underground missile system ranging between 3,000 ft. and 8,000 ft. underground.

That's right -- as much as 8,000 ft. underground.

This 1988 report mentions having the base operational as soon as possible, "within a five-year construction schedule." Five years from 1988 is 1993. Is such a base now operational, far below some unknown location in the United States? Based on my research, I am not certain. However, given the rather substantial paper trail, it is certainly within the realm of possibility that something like it has been secretly built.

The 1988 report calls for a system with tunnels up to 20 miles long, branching off from access shafts. The report's conclusion states, "The consensus of the working groups involved in preparing this report is that the basic technical capabilities to create complex underground facilities at the pace and depth envisioned are available in current practice."[10]

A series of federal contracts for development of the deep underground missile system were let in the mid-1980s by the Air Force's Ballistic Missile Office, at Norton Air Force Base, in California. The contracts that were let do not, in and of themselves, prove that the project has actually been carried out. At the least, though, they do demonstrate that this concept went well beyond a paper, planning stage and began to develop real, hard technology.

United Technologies, Hamilton Standard Division, of Windsor Locks, Connecticut was given a contract in November 1985 for "life support and chemical/biological agent mitigation systems on the Small Intercontinental

Ballsistic Missile (ICBM) Deep Basing Program." The projected completion date for the work was February 1988. The Federal Contract No. was: F04704-85-C-0111.[11] This contract would probably have to do with supply of pure air and water for the crew(s) of an underground base.

In December 1985, BDM of McLean, Virginia was awarded a contract to conduct an "intercontinental ballistic missile (ICBM) deep basing communication study." The contract was to be completed by February 1988; the Federal Contract No. was: F04704-86-C-0045.[12]

In 1986 Bell Aerospace Textron was given a contract for an "ICBM deep basing gas propelled launcher feasibility demonstration." Plans called for completion of the contract by June 1988. The Federal Contract No. was: F04704-86-C-0100.[13] The wording of the contract announcement creates the image of a nuclear missile being ejected into flight from the mouth of a tunnel bored to the surface from deep underground.

In 1987 Earth Technology, of San Bernardino, California was awarded a multi-million dollar increase to a previously awarded contract, in order to carry out what the Department of Defense rather fuzzily referred to as "geotechnical and siting deep basing fine screening Phase I and II."[14] In ordinary language this would seem to mean that the Ballistic Missile Office paid this company millions of dollars to do a two-phase geological and technical study, to fine screen sites where a deep underground missile base would be located. The Federal Contract No. was: F04704-85-C-0084.

And finally, the Robbins Company, of Kent, Washington (the tunnel boring machine manufacturer mentioned in the Air Force Weapons Laboratory/Colorado School of Mines two-volume report mentioned above) was awarded a contract in 1985 for "egress/excavation

development and testing."[15] Presumably, this refers to excavation for egress of nuclear missiles from deep underground, since the contract was let by the Ballistic Missile Office at Norton Air Force Base. The Federal Contract No. was: F04704-85-C-0112.

So is there really a secret, military tunnel system? The short answer to this question is: I am not certain.

But the documents, articles and contracts referred to above suggest it is entirely possible that the military, working through the Ballistic Missile Office at Norton Air Force Base, with the probable assistance of the Army Corps of Engineers and private companies such as Robbins, Earth Technology, and others, has secretly built an extensive, very deeply buried tunnel system and nuclear missile complex, somewhere in the United States, perhaps somewhere in the West.

If it has been made, this system may be, in its totality, hundreds of miles long and thousands of feet underground. If it exists it is certainly very well hidden. And if it exists it may very well explain either partly or wholly the recurrent rumors in UFOlogy about a secret tunnel system in the southwestern United States. But even if it has not been built, the extensive plans, studies, and various contracts referred to above would be sufficient to fuel rumors about the existence of such a tunnel system.

From the standpoint of disinformation there is another possibility: that the military has really built a tunnel system of the sort described here, but has tried to hide its existence under a tabloid-style cover story of alien tunneling activities. According to this hypothetical scenario the military would count on the "alien" connection to be sufficiently ridiculous in the public eye that if word of the tunnels ever surfaced in the media they could be discounted as the fevered imaginings of daffy UFOlogists

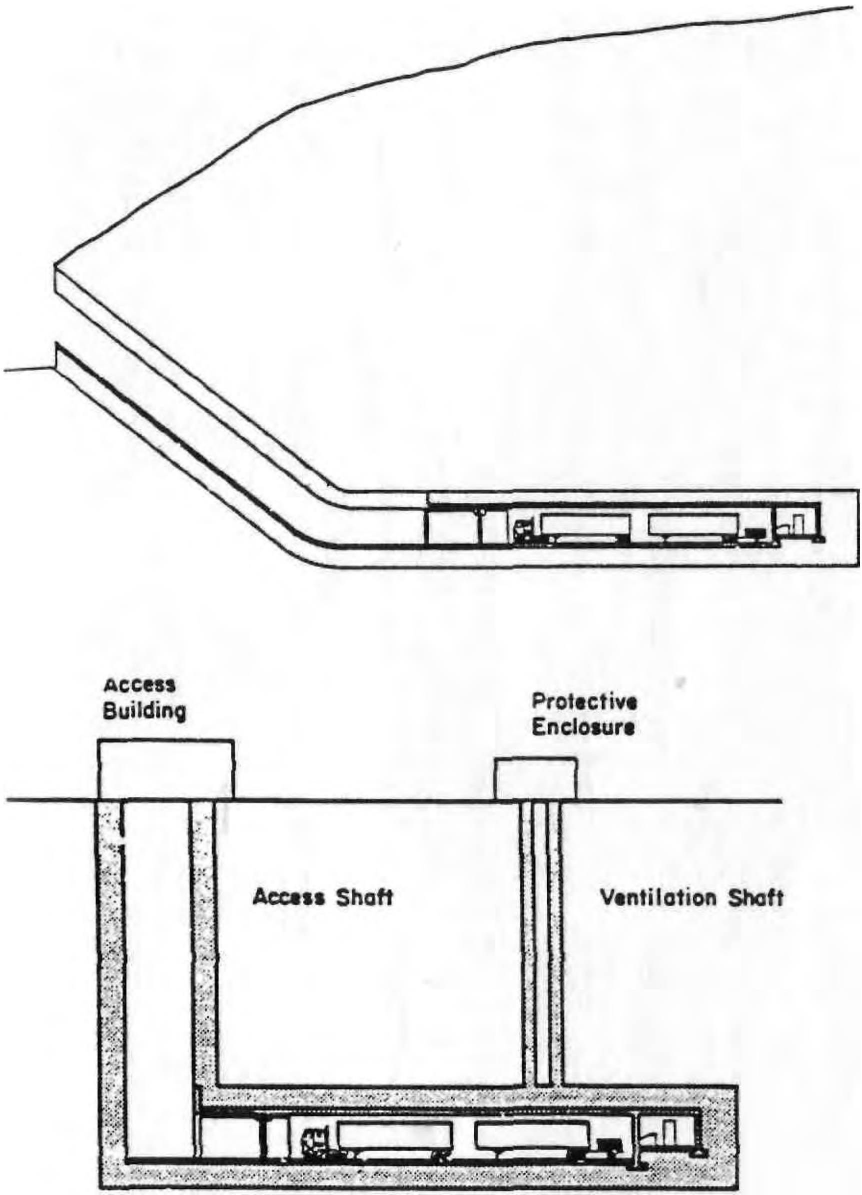


ILLUSTRATION 1 - Even though hidden from public view behind layers of high security, entrances to underground bases neverthless can be big enough to literally drive a truck into. Two means of approach are shown here. Source: U.S. Army Corps of Engineers, Literature Survey of Underground Construction Methods for Application to Hardened Facilities.

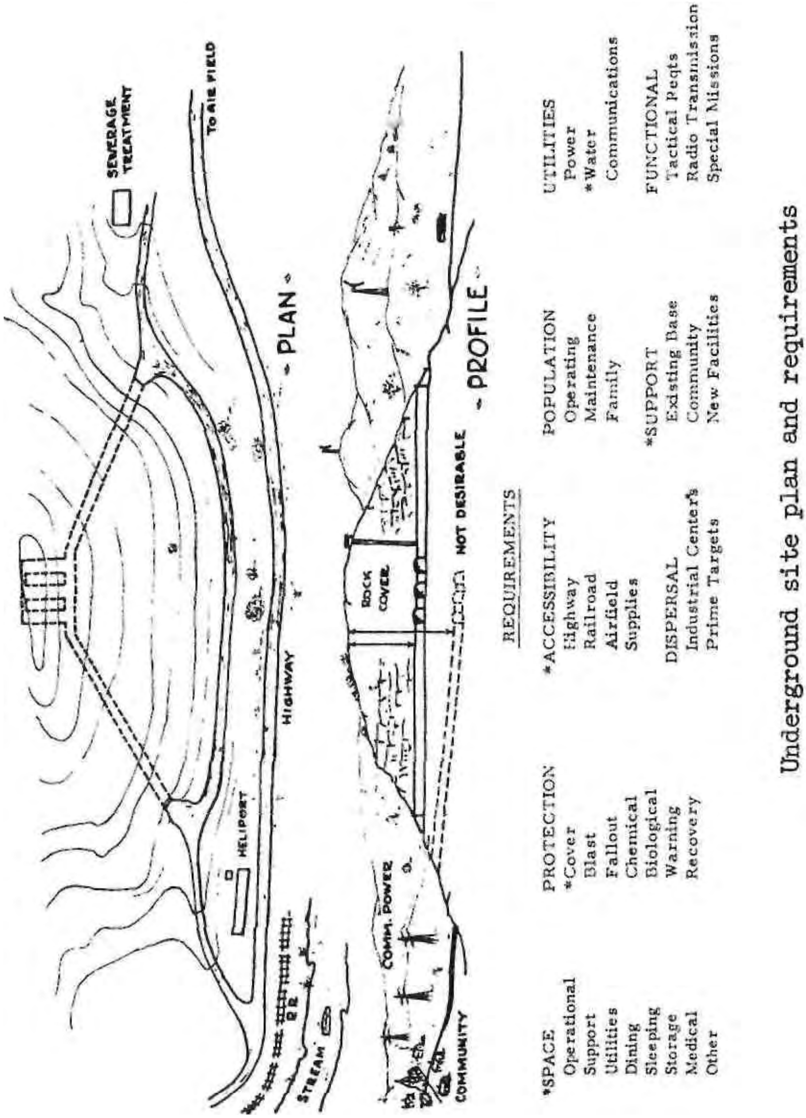


ILLUSTRATION 2 - Example of Army Corps of Engineers plan for an underground base, circa late 1950s. Notice the microwave towers for communication and planned proximity to a community, highway, railroad tracks and power lines. Note, too, that two entrances are preferred and that there is a vertical shaft to the surface as well, perhaps for air. Source: M.D. Kirkpatrick, in Protective Construction in a Nuclear Age: Proceedings of the 2nd Protective Construction Symposium. 24-26 March 1959. Vol. I ed. J.J. O'Sullivan (New York: The Macmillan Co., 1961).

Illustration 3 - There is an underground facility beneath this ridge in the Manzano foothills on the outskirts of Albuquerque, New Mexico. This underground installation, begun in the late 1940s, is on Kirtland Air Force Base. Photo by the author.

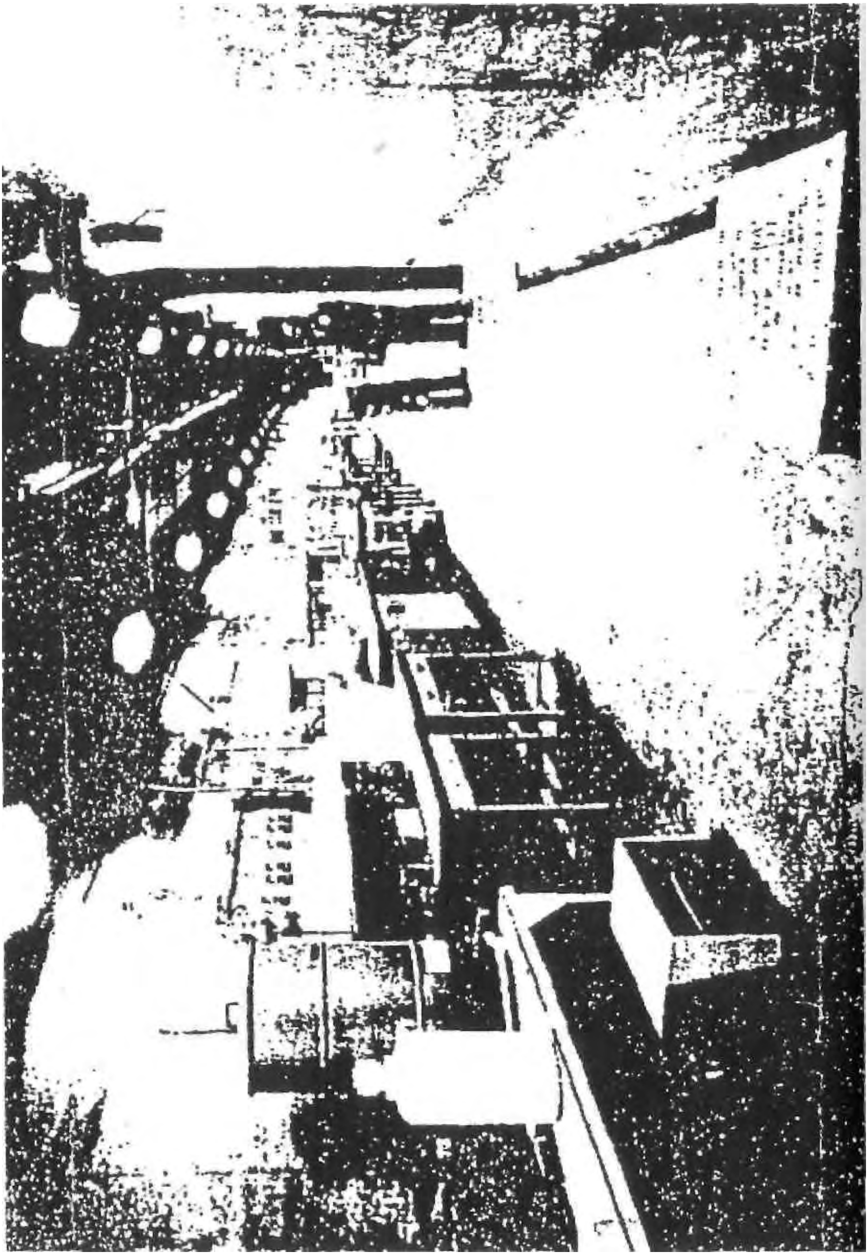
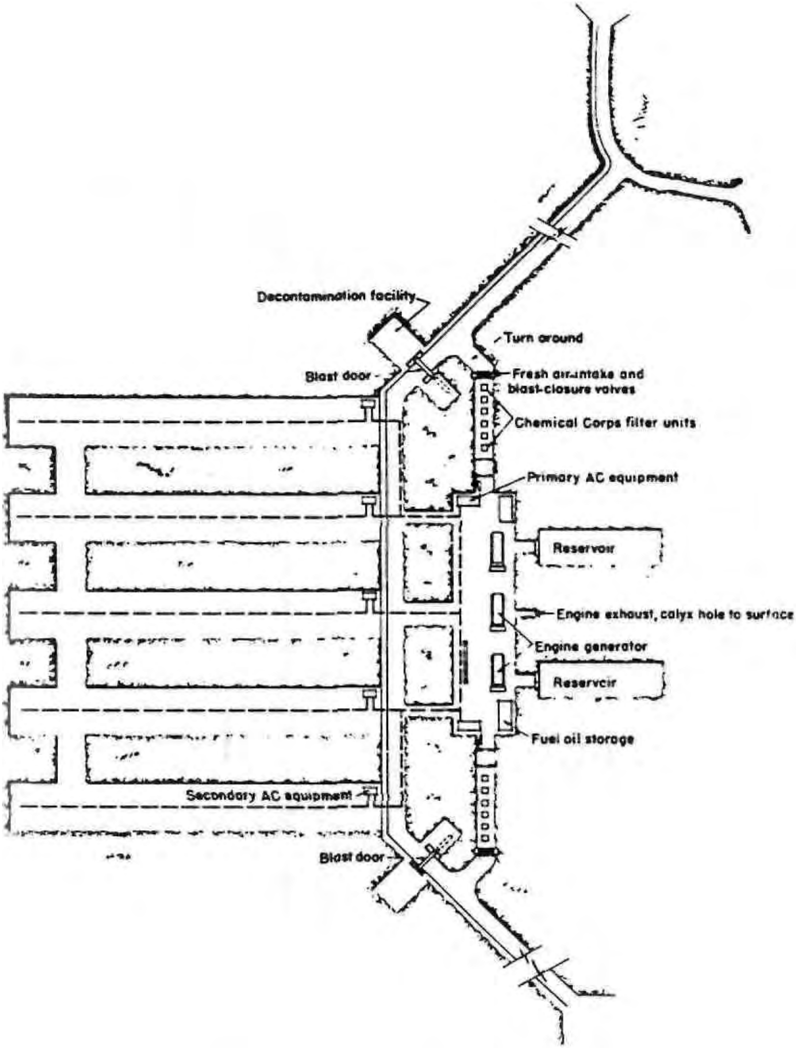
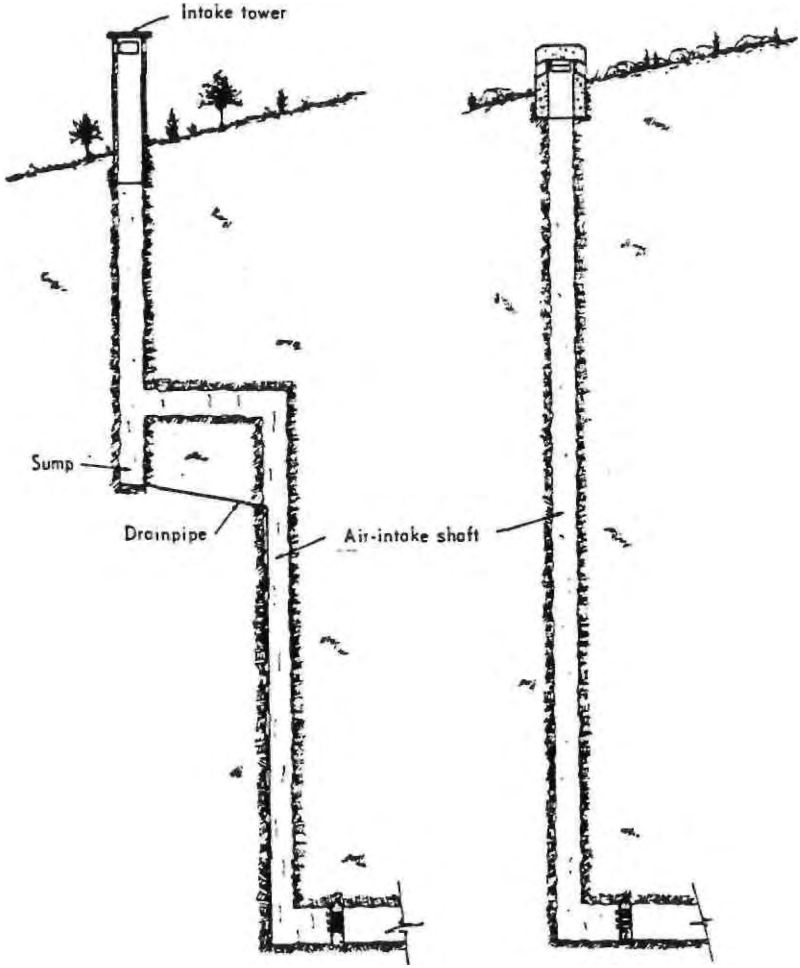


ILLUSTRATION 4 - An underground chamber in the mysterious Los Alamos Lab facility, circa 1940s. After repeated requests, the Department of Energy released a badly blurred photostatic copy of a magazine article that included this photograph. See Pages 27-30 for the whole story. Original publication unknown.



Example of underground plant arrangement

ILLUSTRATION 5 - Even in the 1950s, military planning for sizeable underground installations was in full swing. Note the decontamination room, the chemical filter units, the blast closure valves on the fresh air intake units, and the water reservoirs. From U.S. Army Corps of Engineers, Design of Underground lnstallations in Rock: Protective Features and Utilities.



Example of air-intake shafts

ILLUSTRATION 6 - Two ways of protecting the fresh air intake from above ground, circa 1950s. From U.S. Army Corps of Engineers, Desisn of Underground Installations in Rock: Protective Features and Utilities.

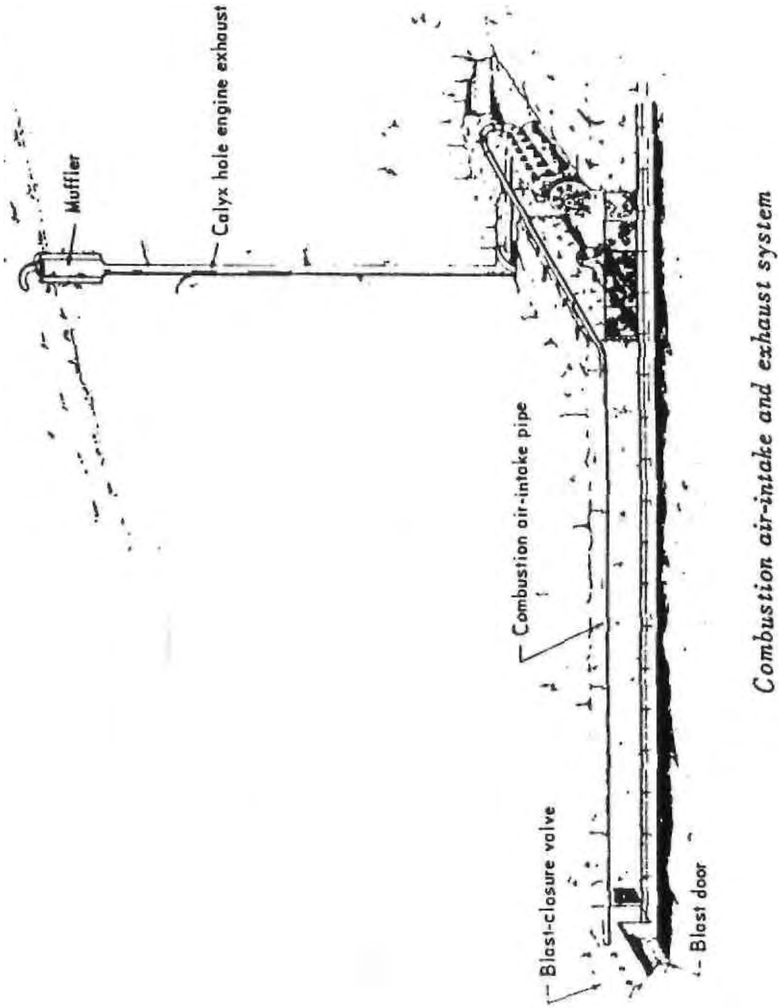


ILLUSTRATION 7 - Machinery powered by internal-combustion engines underground would use up valuable breathing air, so the military planners in the 1950s devised a way to supply air to the machines, and exhaust the fumes. Source: U.S. Army Corps of Engineers, Design of Underground Installations in Rock: Protective Features and Utilities.

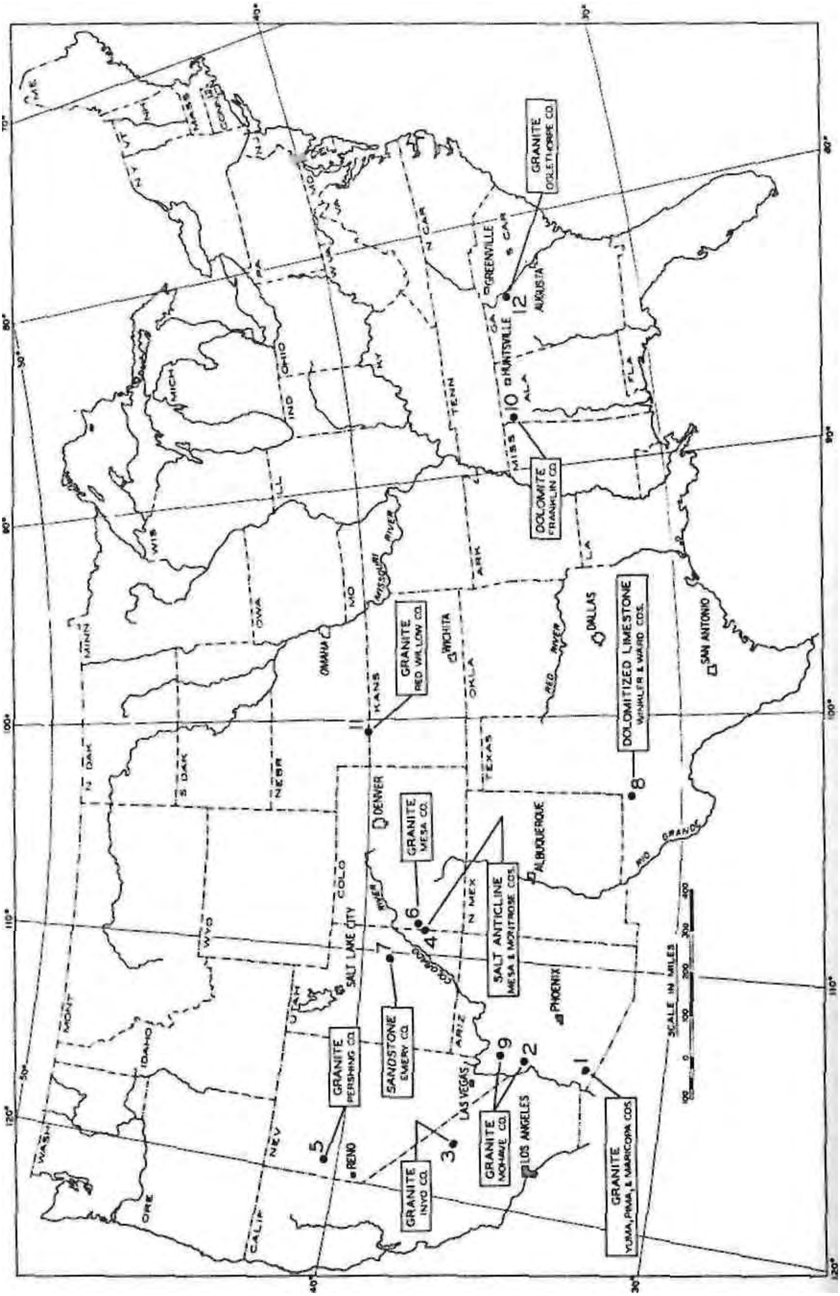
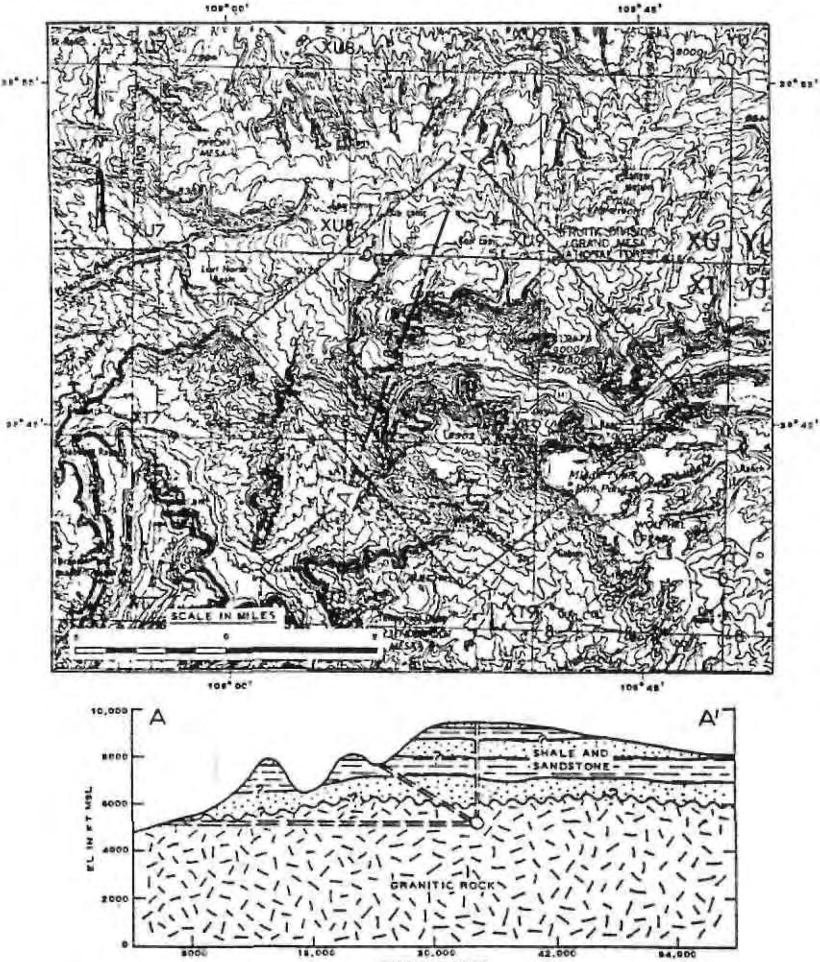


ILLUSTRATION 8 - In 1964, the Army Corps of Engineers picked 12 sites suitable for the construction of 600-ft. diameter cavities 4,000 ft. underground, for the purpose of setting off nuclear bomb test explosions. Source: U.S. Army Corps of Engineers, Feasibility of Constructing Large Underground Cavities. Vol I.



SCHEMATIC GEOLOGIC SECTION SHOWING LOCATIONS OF VERTICAL SHAFT, HORIZONTAL, AND INCLINED ACCESS IN GRANITIC ROCK OVERLAIN BY SEDIMENTARY COVER

Site 6, granite with sedimentary cover, Mesa County, Colorado

ILLUSTRATION 9 - One of the sites selected by the U.S. Army Corps of Engineers In 1964, suitable for constructing a large cavity, deep underground, for testing nuclear bombs. Note that the horizontal option for access takes the form of a tunnel miles long. Source: U.S. Army Corps of Engineers, Feasibility of Constructing Large Underground Cavities, Vol. I.

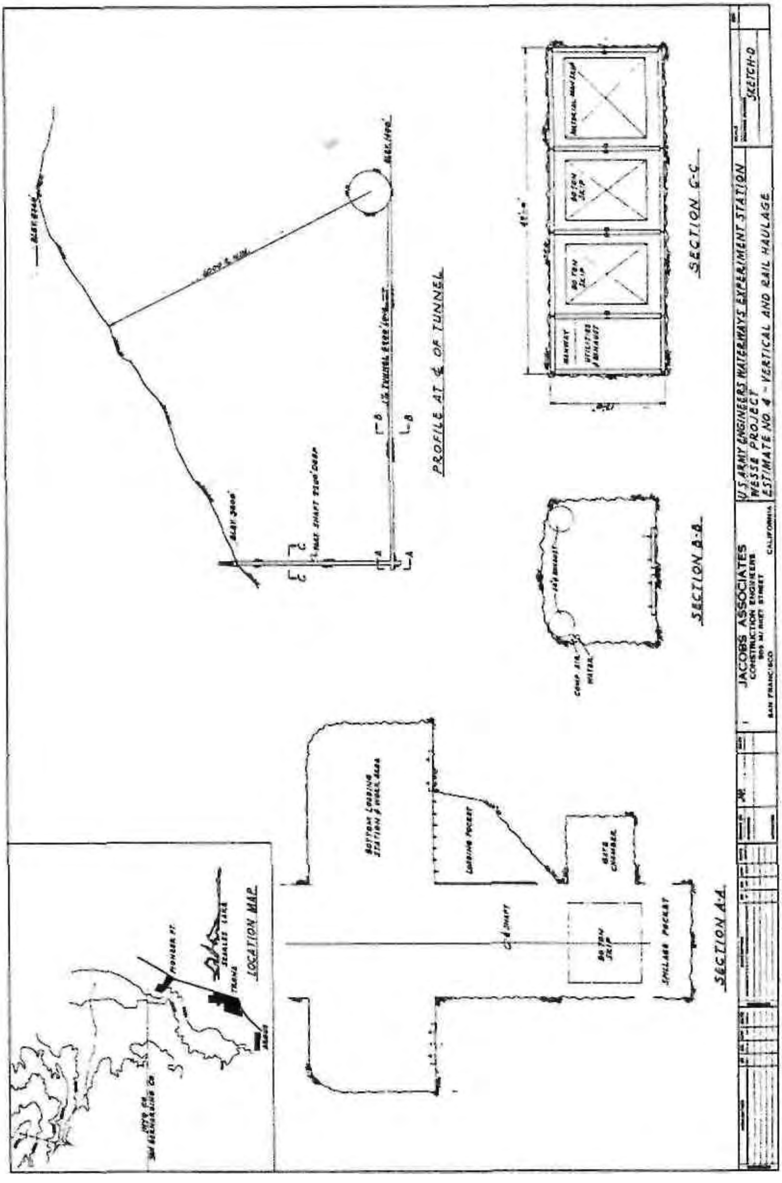


ILLUSTRATION 10 - A 1964 plan from the Army Corps of Engineers to construct a large underground cavity 4,000 feet underneath Argus Peak, northwest of Trona, California. If built, this facility would today be within the boundaries of the China Lake Naval Weapons Center, which has long been rumored to be the site of a massive underground installation. Source: U.S. Army Corps of Engineers, Feasibility of Constructing Large Underground Cavities. Vol. III.

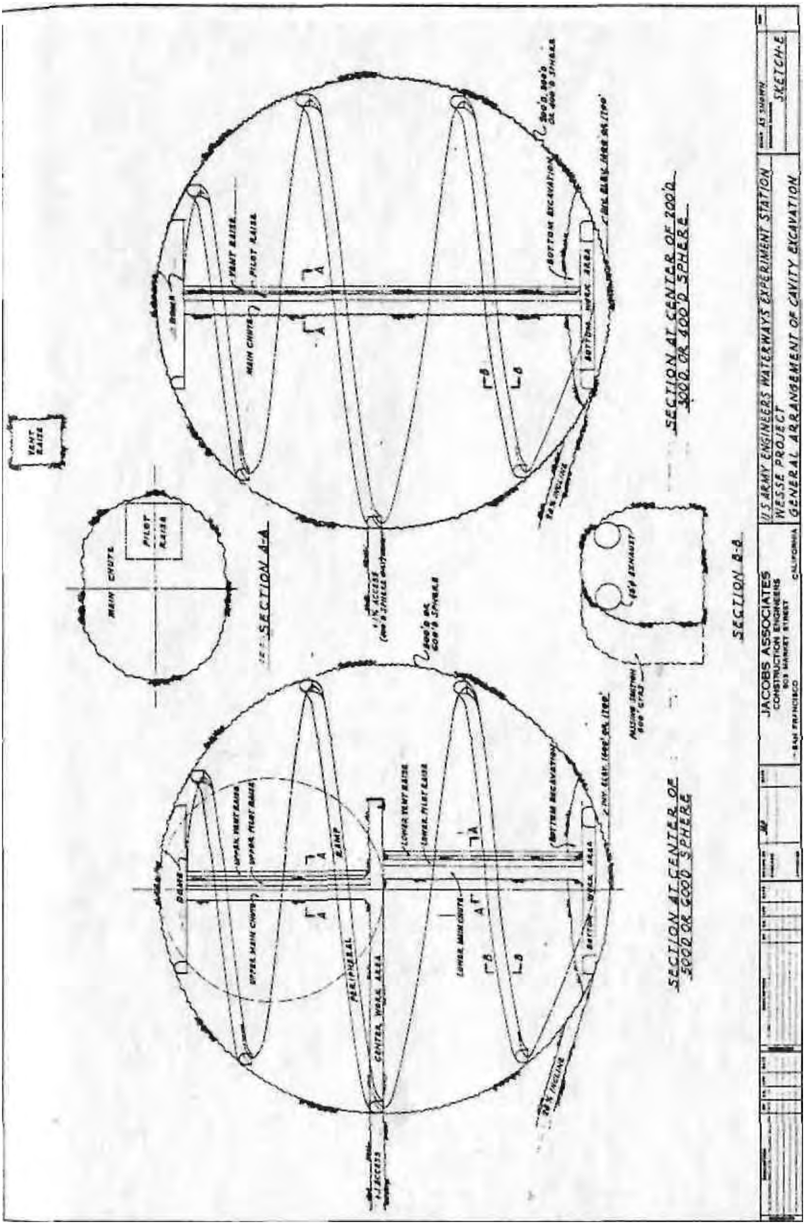


ILLUSTRATION 11 - A beautiful piece of drafting work from the Army Corps of Engineers, circa 1964. Was this facility, proposed for construction within the boundaries of present-day China Lake Naval Weapons Center, northwest of Trona, California, ever built? Source: U.S. Army Corps of Engineers, Feasibility of Constructing Large Underground Cavities, Vol. III.

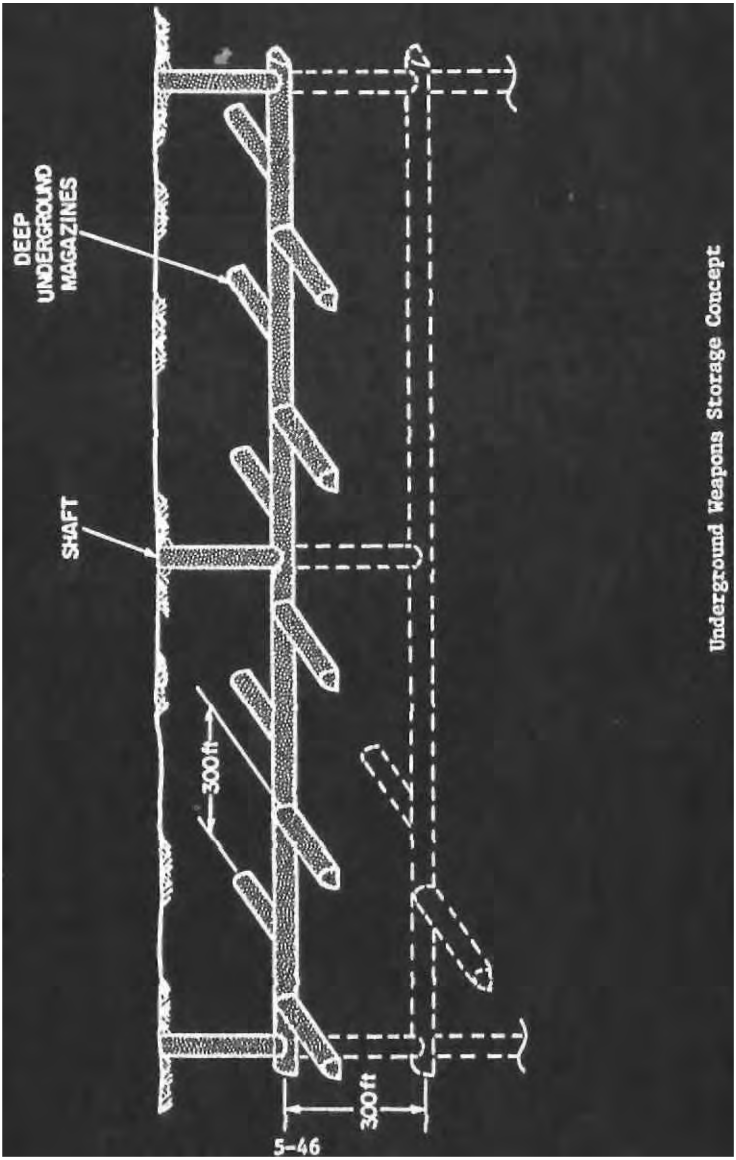


ILLUSTRATION 12 - You'd think the Navy would stick to the water, but no -- they have plans to dig underground, too. Here they're figuring out how to store and hide their weapons. Source: R. Hibbard, et. al., Subsurface Deployment of Naval Facilities, 1972.

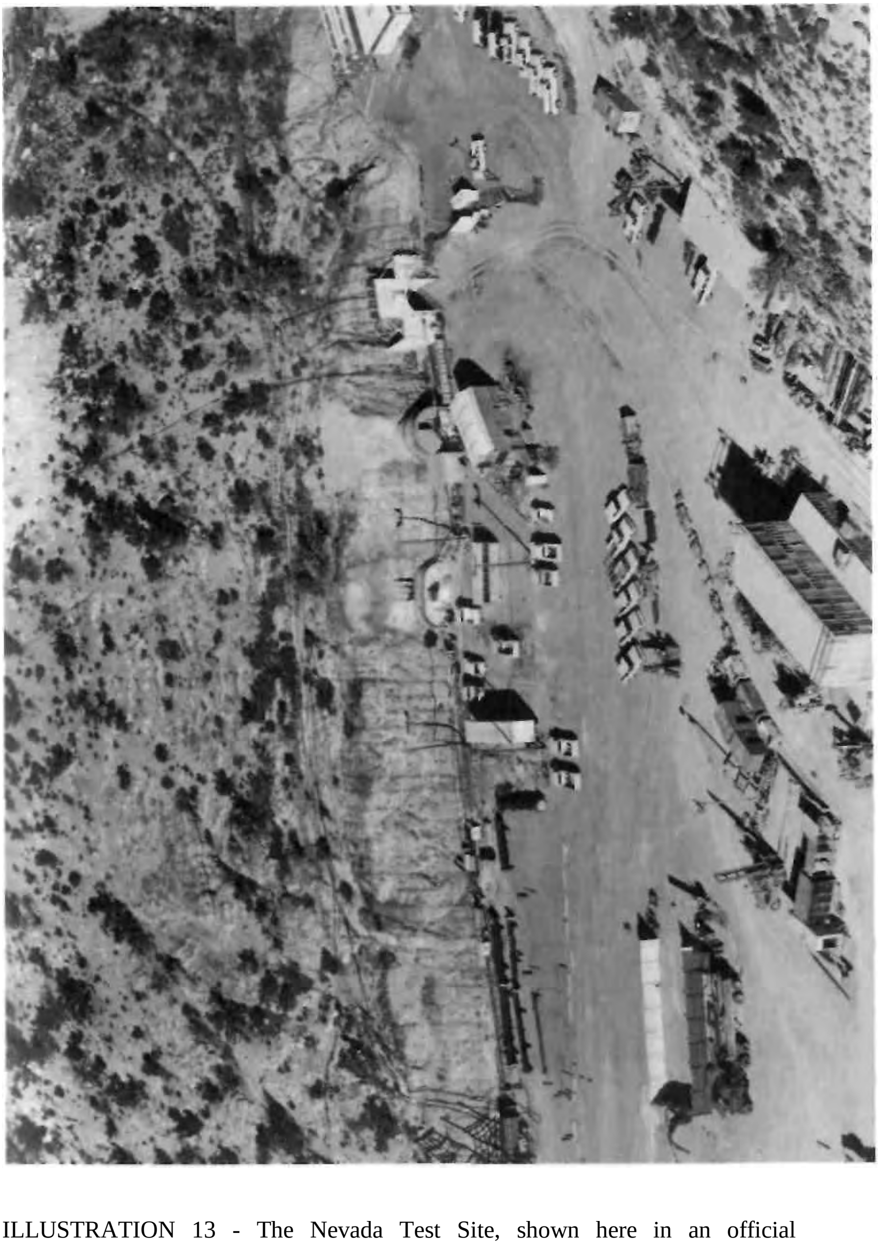


ILLUSTRATION 13 - The Nevada Test Site, shown here in an official Department of Energy photo taken in 1980, at the time of a less than 20-kiloton nuclear bomb test that took place 1,280 feet beneath Rainier Mesa. The test, designed by the Los Alamos National Laboratory, was conducted for the U.S. Defense Nuclear Agency. There are three underground entrances visible; one is large enough to receive a train. The numerous parked trucks are reminders of the large numbers of people who work underground. They're not likely, though, to discuss their work with you: the secrecy oaths that they sign are very intimidating. Department of Energy photo.

ILLUSTRATION 14 - Miners at work in tunnels beneath Rainier Mesa at the Nevada Test Site. They're stabilizing the walls with rock bolts and epoxy so that when the nuclear explosions go off, the walls won't crumble. Department of Energy photo.

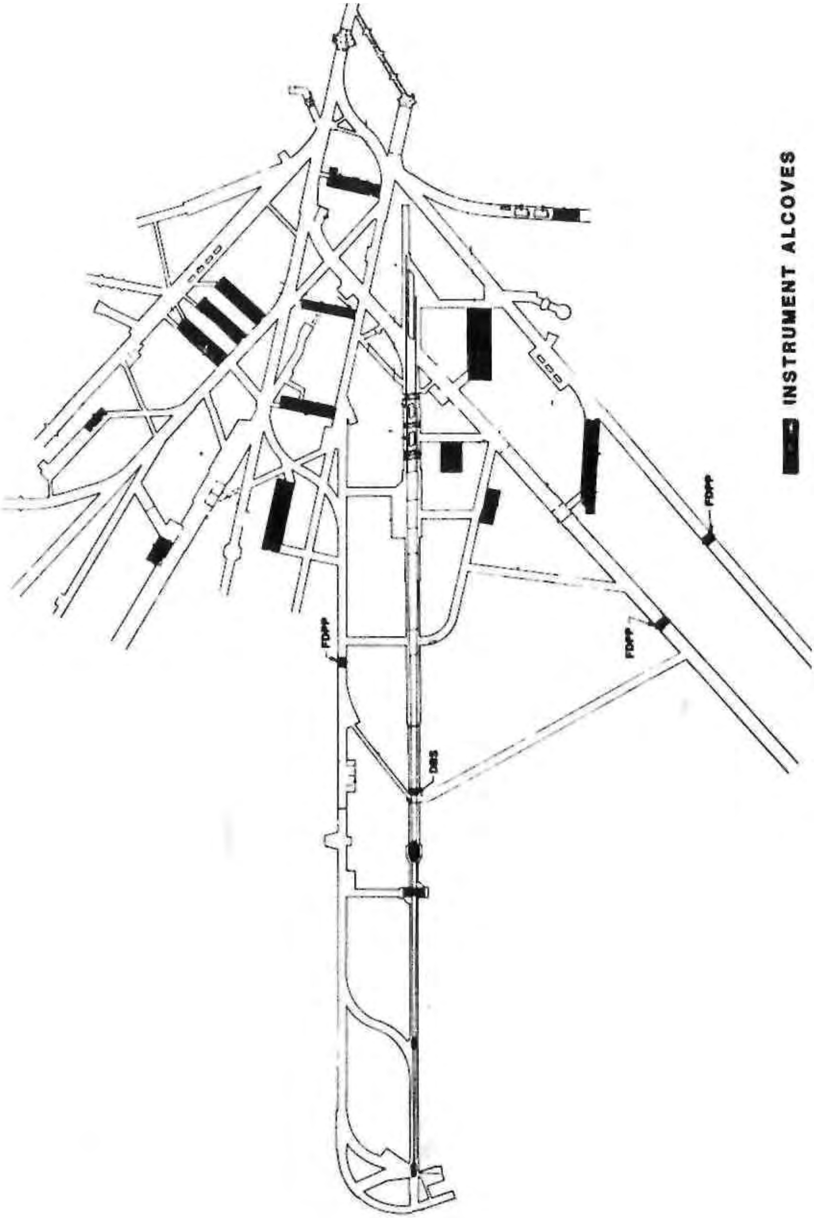


ILLUSTRATION 15 - A partial map of "N" Tunnel, just one of the many tunnel complexes at the Nevada Test Site. Most of the black boxes are instrument alcoves. This labyrinth of passageways and tunnels - and it's only a fragment of the whole - reveals how much time and energy has been spent underground by just part of just one government agency at just one site. Deparment of Energy photo.

ILLUSTRATION 16 - A "line-of-sight" pipe under construction under Rainier Mesa at the Nevada Test Site. These pipes, which can be up to 27 ft. in diameter, serve as test chambers that house monitoring equipment. They are placed 900 to 2,000 ft. from the nuclear blast. Defense Nuclear Agency photo.

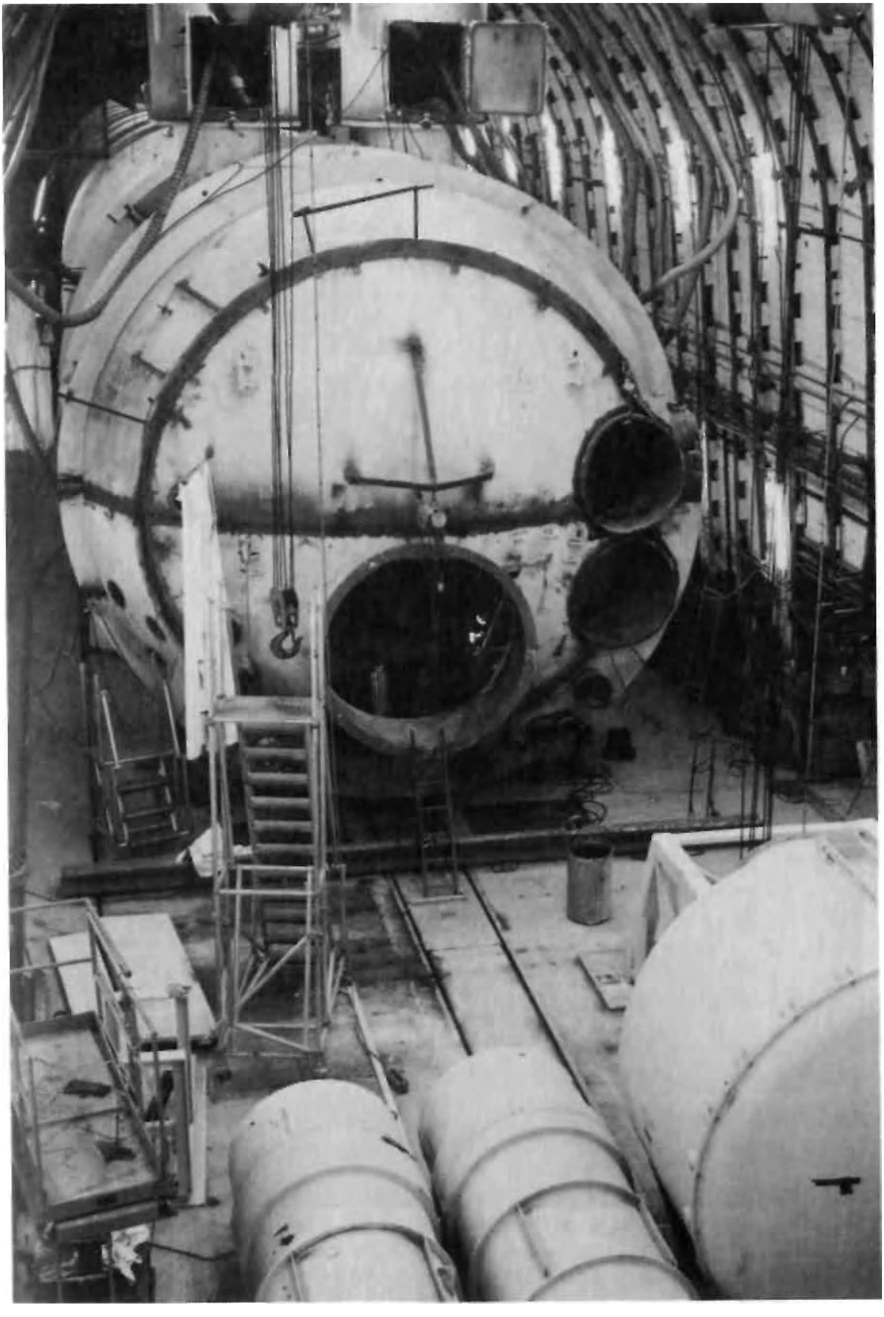


ILLUSTRATION 17 - Construction of nuclear test monitoring chambers in a tunnel under Rainier Mesa, at the Nevada Test Site. Department of Energy photo.

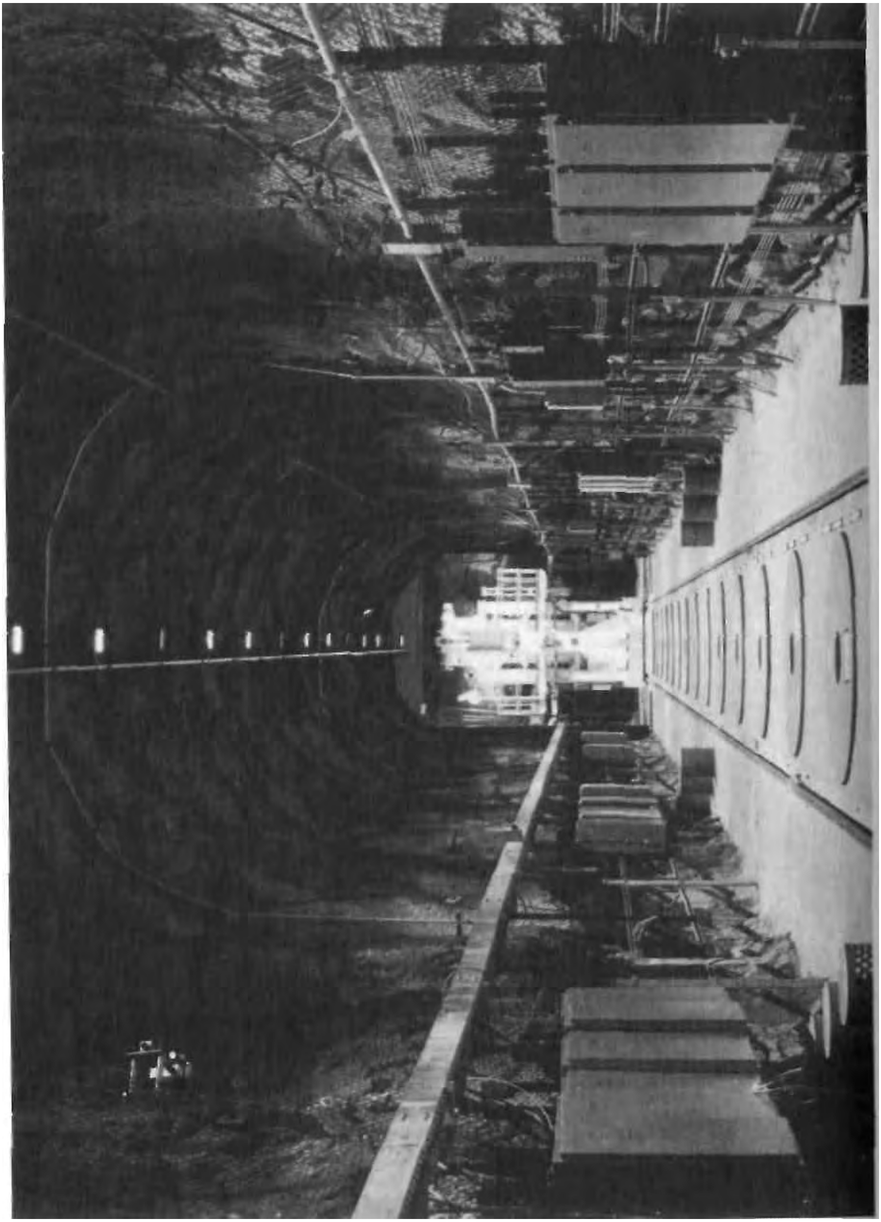
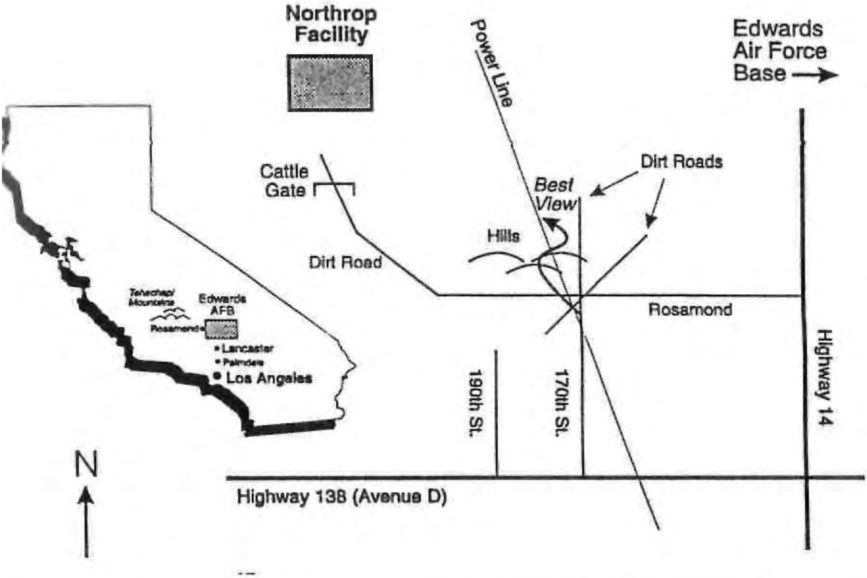


ILLUSTRATION 18 - The one problem -- and it's a big one -- that the nuclear industry has not yet solved is what to do with nuclear waste. This test, run from 1980-83 at the Nevada Test Site, evaluated the effects of storing spent reactor fuel in a granite formation, 1,400 ft. underground. The spent nuclear fuel elements are in steel-lined holes in the floor, capped by 5,000 lb. concrete plugs. Department of Energy photo.



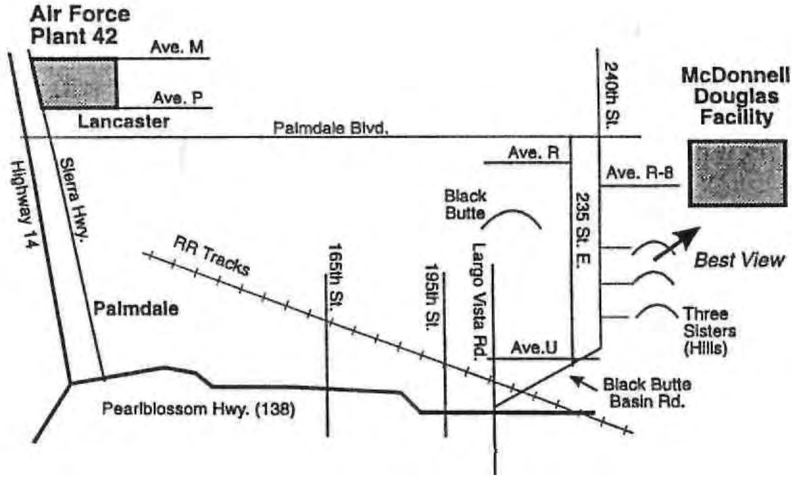


ILLUSTRATION 19 - Local maps for finding the Northrop and McDonnell Douglas facilities in the Antelope Valley of Southern California.The Northrop facility is rumored to have as many as 42 underground levels. These plants feature strange installations not unlike the photographs from the Lockheed Plant in Hellendale, California (See Illustrations 20 and 21). This whole area is reported to be a great place to spot very unconventional aircraft. This illustration reprinted with permissionfrom the November 1992 HUFON Report, the newsletter of the Houston UFO Network, PO Box 942, Bellaire, TX 77402 (713)850-1352.

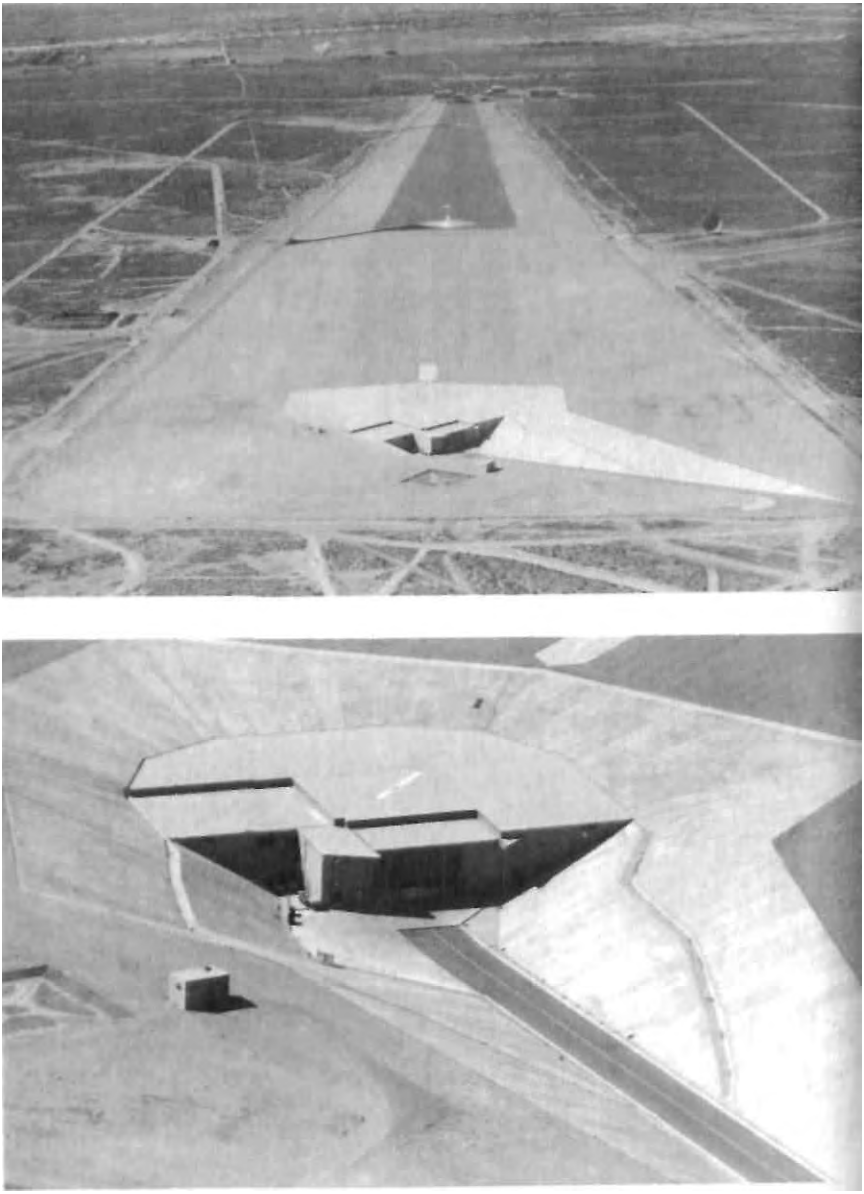


ILLUSTRATION 20 - Lockheed's mysterious Hellendale, California facility. The underground entrance (shown in close-up in lower photo) is in foreground. Although the long paved surface would seem to be a landing strip, it is interrupted by two huge pylons, which serve to render this "landing strip" unusable for conventional fixed-wing aircraft. Photos collection of the author.

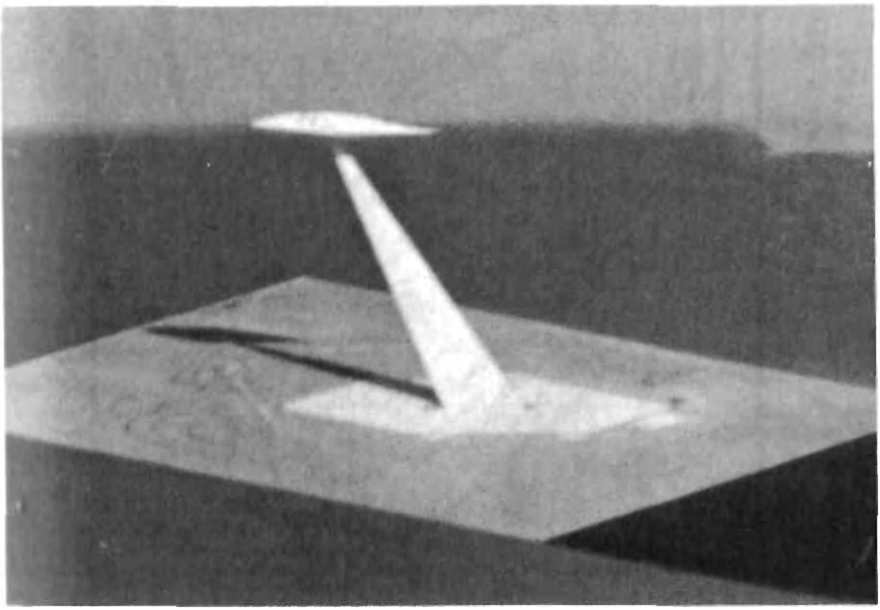


ILLUSTRATION 21 - Long shot and close-up view of unknown object on a test pylon at Lockheed's Hellendale, California facility. The pylon can be lowered into an underground chamber until it disappears from view (the white area around its base are doors which open and close). Some reports say that this is a radar testing facility, and the antenna dish bounces radar waves off test objects. Photos collection of the author.

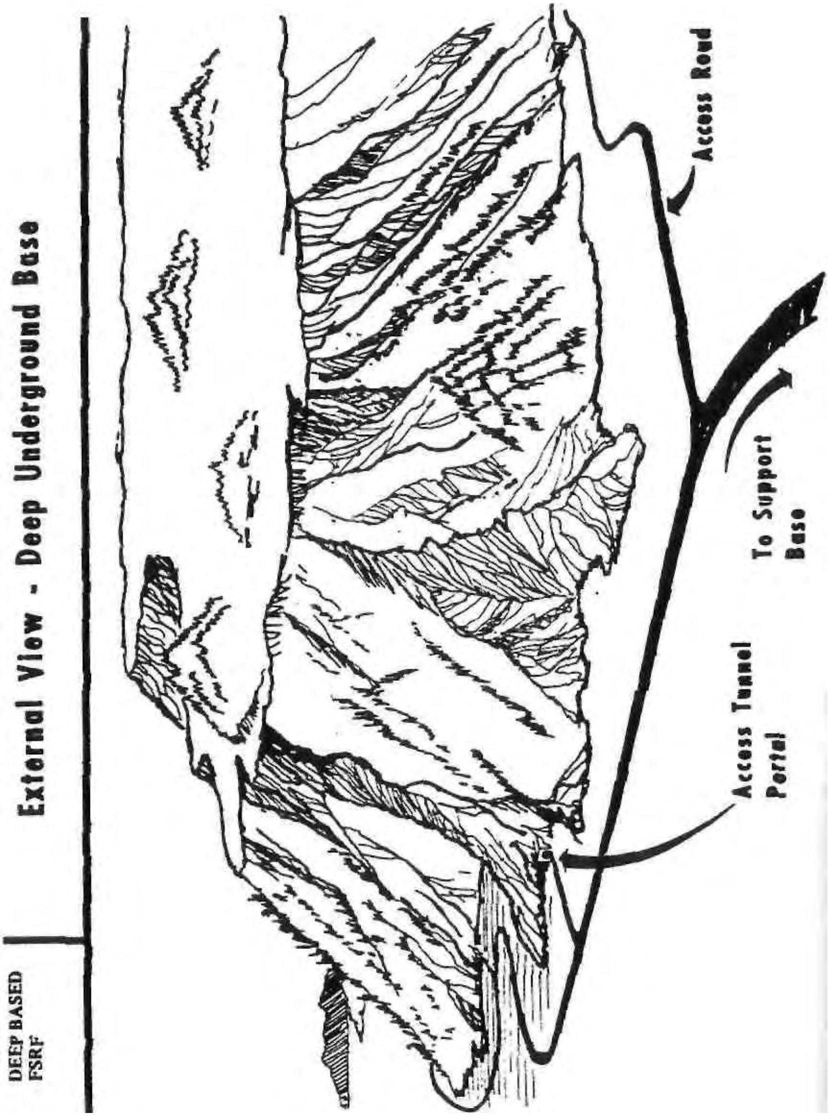


ILLUSTRATION 22 -A 1982 report from the U.S. National Committee on Tunneling Technology contained this picture of what a deep underground base for strategic missiles would look like - from the outside. Source: Design and Construction of Deep Underground Basing Facilities for Strategic Missiles. Vol 2. Briefings on Systems Concepts and Requirements. Fed. Doc No. NRC/CETS/TT-82-2.

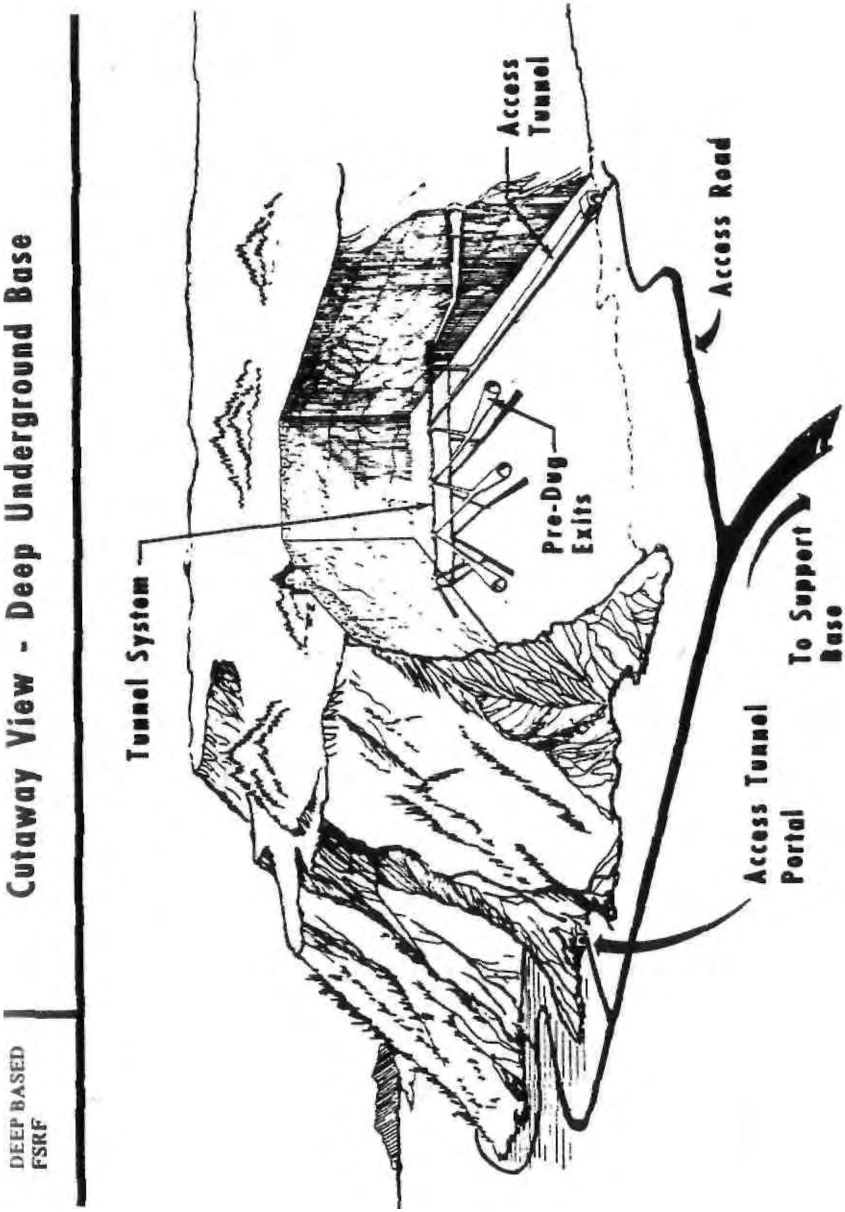


ILLUSTRATION 23 - Cutaway view of a deep underground base. Note the pre-dug exits for possible missile launchers. Source: Design and Construction of Deep Underground Basing Facilities for Strategic Missiles, Vol 2. Briefings on Systems Concepts and Requirements, Fed. Doc. No. NRC/CETS/TT-82-2.

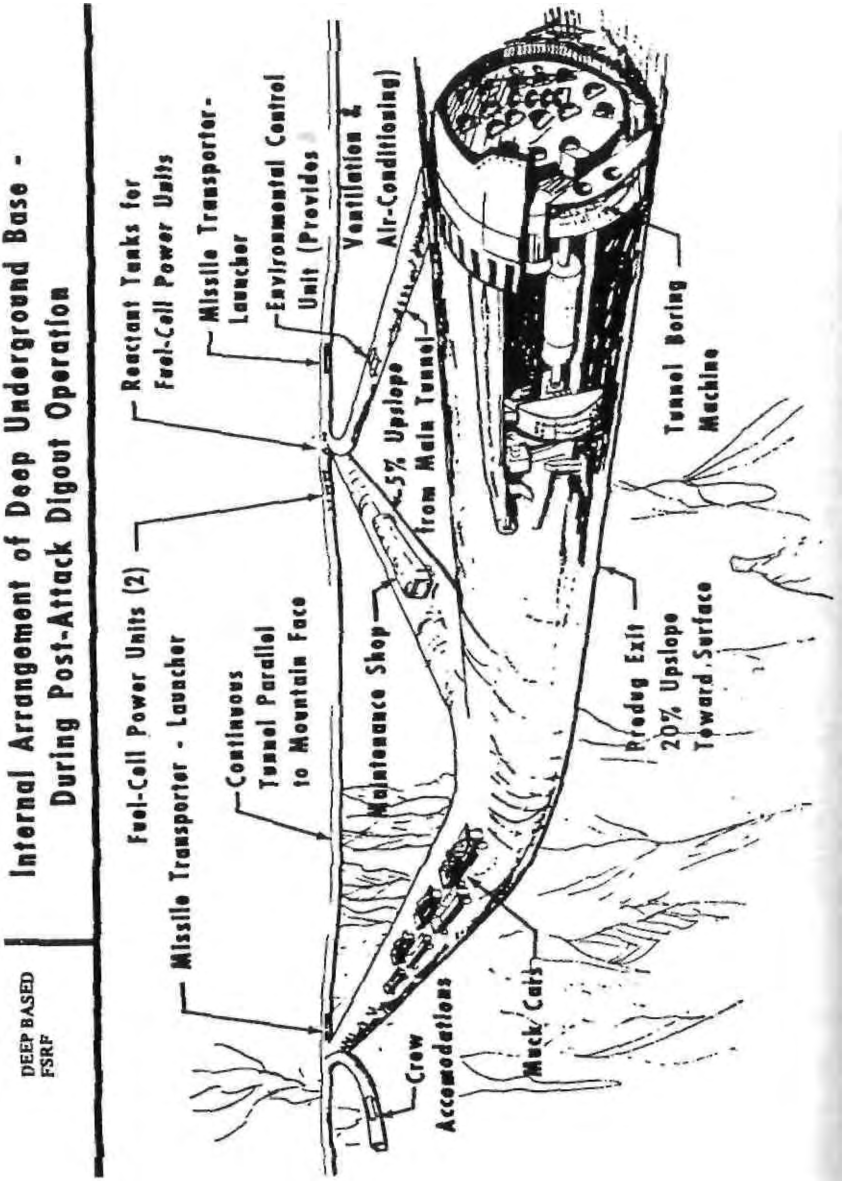
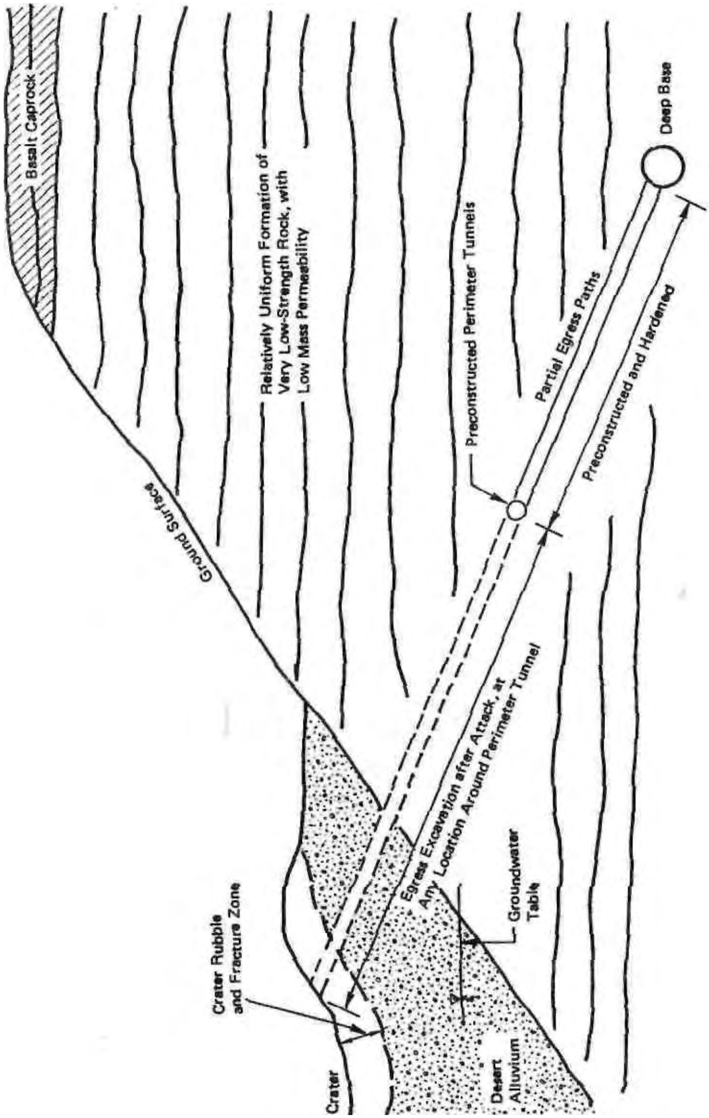


ILLUSTRATION 24 - The tunnel boring machine (TBM) inside the pre-dug exit goes into action and bores the rest of the way out from deep underground. In this representation, the missile transporter and launcher are in the background. Source: Design and Construction of Deep Underground Basing Facilities for Strategic Missiles, Vol. 2, Briefings on Systems Concepts and Requirements, Fed. Doc. No. NRC/CETS/TT-82-2.



Egress through very low-strength rock with crater in alluvium; preconstructed partial egress paths to perimeter tunnel.

ILLUSTRATION 25 - Here's a side view of the post-attack dig-out tunnel. Source: Design and Construction of Deep Underground Basing Facilities for Strategic Missiles. Vol. 1. Evaluation of Technical Issues. Fed. Doc. No. NRC/CETS/TT-82-1.

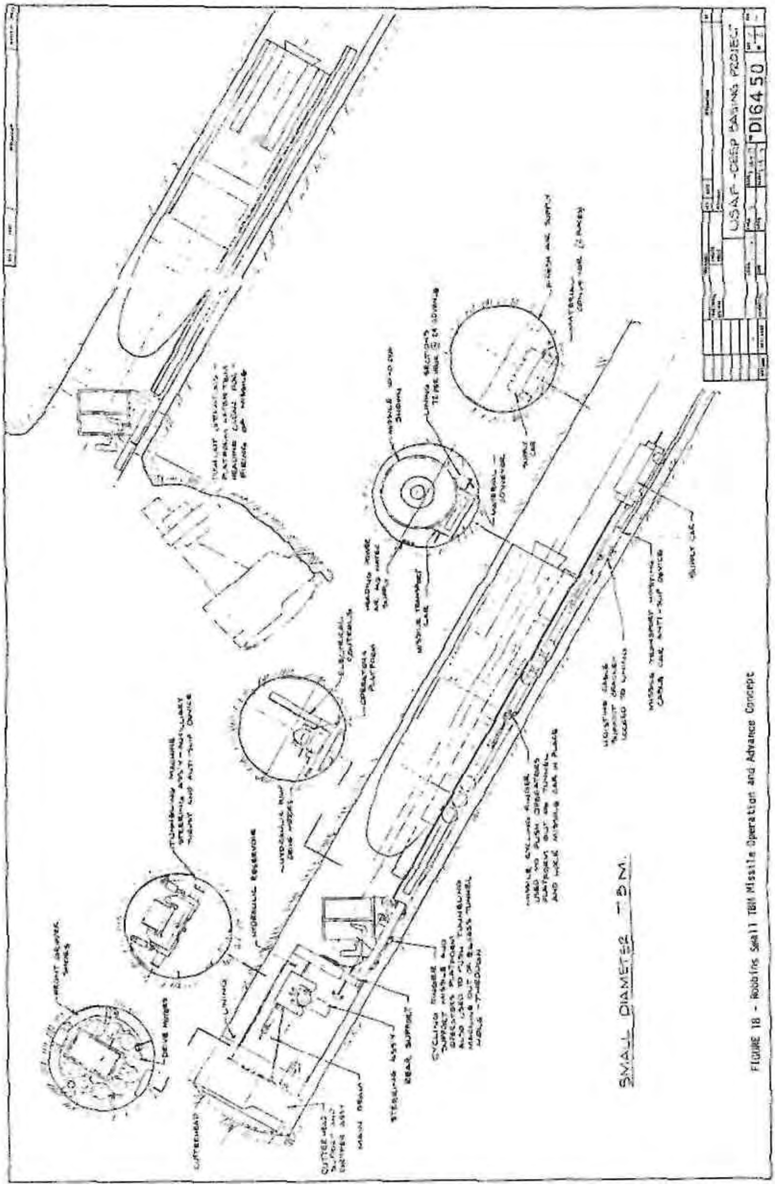


ILLUSTRATION 26 - Here's a detailed schematic from the Air Force for a combination tunnel-boring machine and nuclear missile launcher that would be used to dig out of a deep underground missile base and fire a missile. The deep base would be at least a half mile underground. Source: Tunnel boring Machine Technology for a Deeply Based Missile System. Vol 1. Pt. 1. Application Feasibility. Fed. Tech. Doc. No.AFWL-TR-79-120 (August 1980).

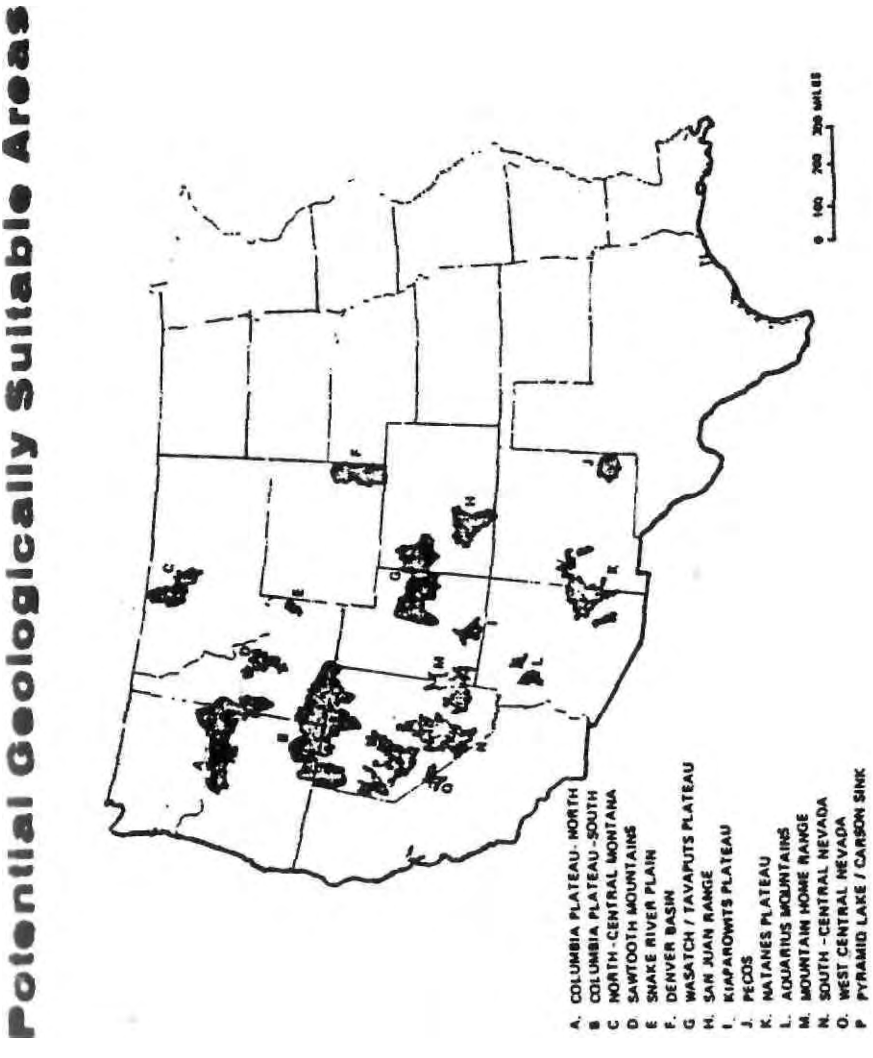


ILLUSTRATION 27 - The government identified these 16 spots as potential sites for deep underground basing facilities for strategic nuclear missiles. Source: Design and Construction of Deep UndergroundBasing Facilities for Strategic Missiles. Vol. 2. Briefings on Systems Concepts and Requirements. Fed. Doc. No. NRC/CETS/TT-82-2.

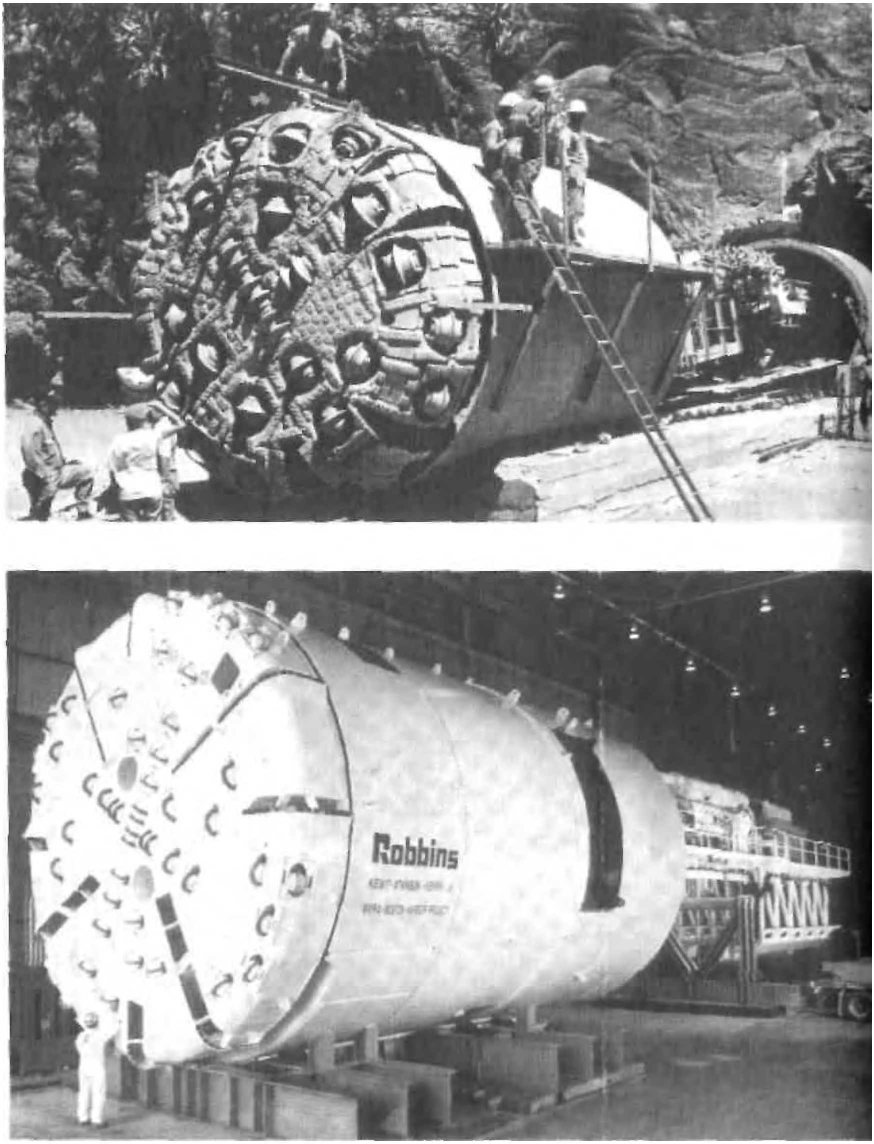


ILLUSTRATION 28 - Two tunnel boring machines (TBMs) sold by The Robbins Company. The top model was built for La Reunion irrigation project; the bottom one for Boston Outfall. The front ends of these TBMs chew away the rock; the structures that trail behind house the operators and carry away the muck. Photos used with permission from The Robbins Company.

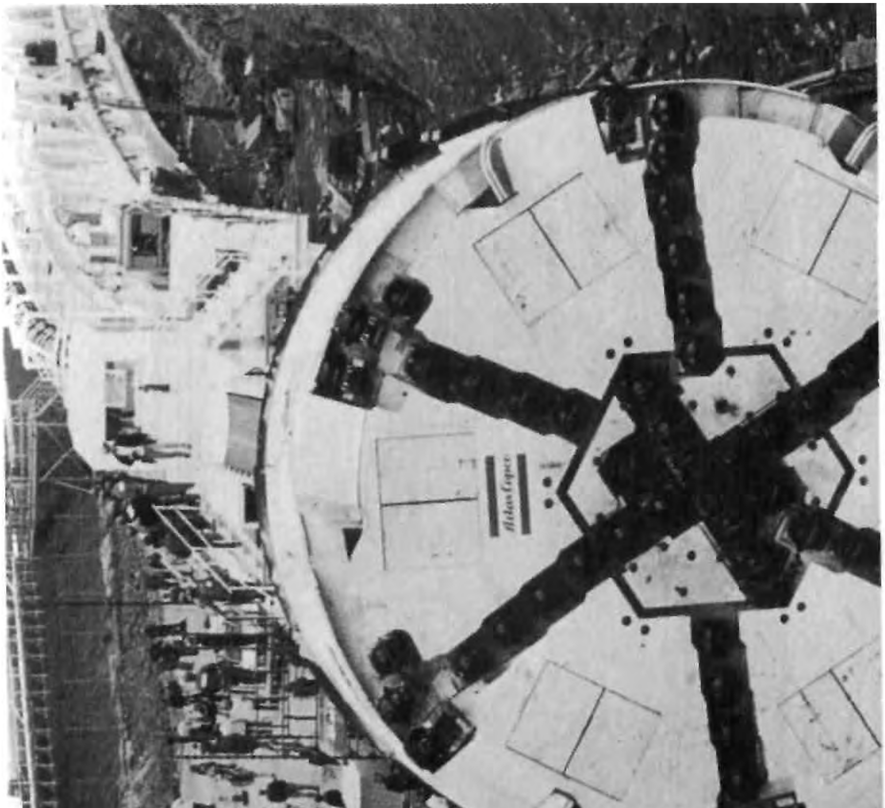


ILLUSTRATION 29 - This Jarva MK27 model was used to build the Hallandsas rail tunnel in Sweden. Photo used with permission from The Robbins Company.

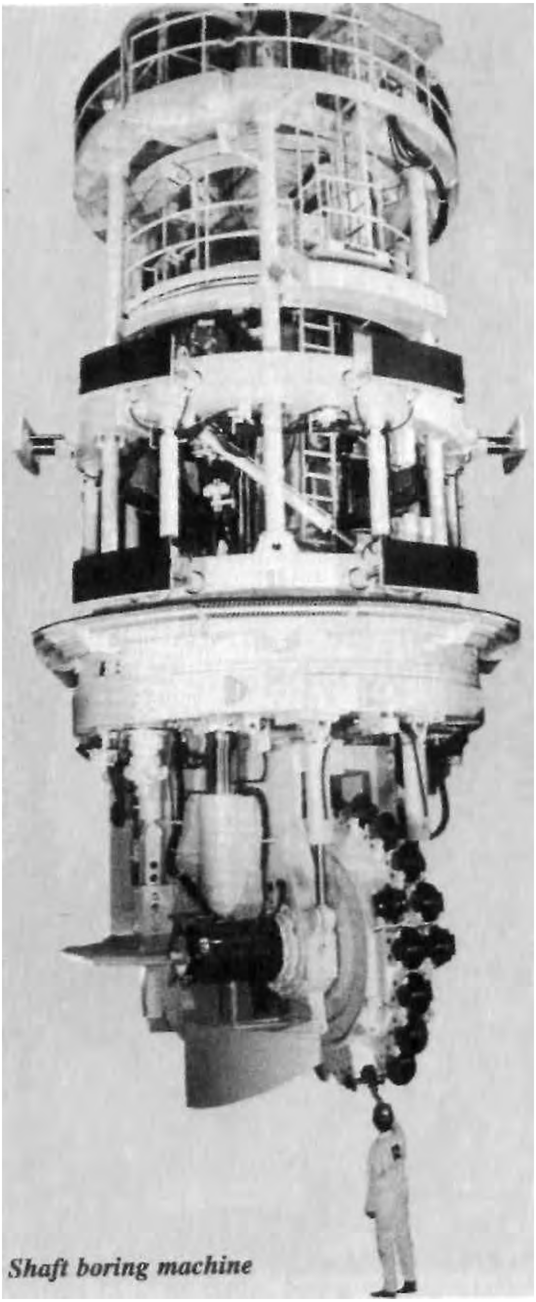


ILLUSTRATION 30 - The Robbins Company manufactures huge shaft-boring machines for excavating large vertical shafts. Photo used with permission from TheRobbins Company.

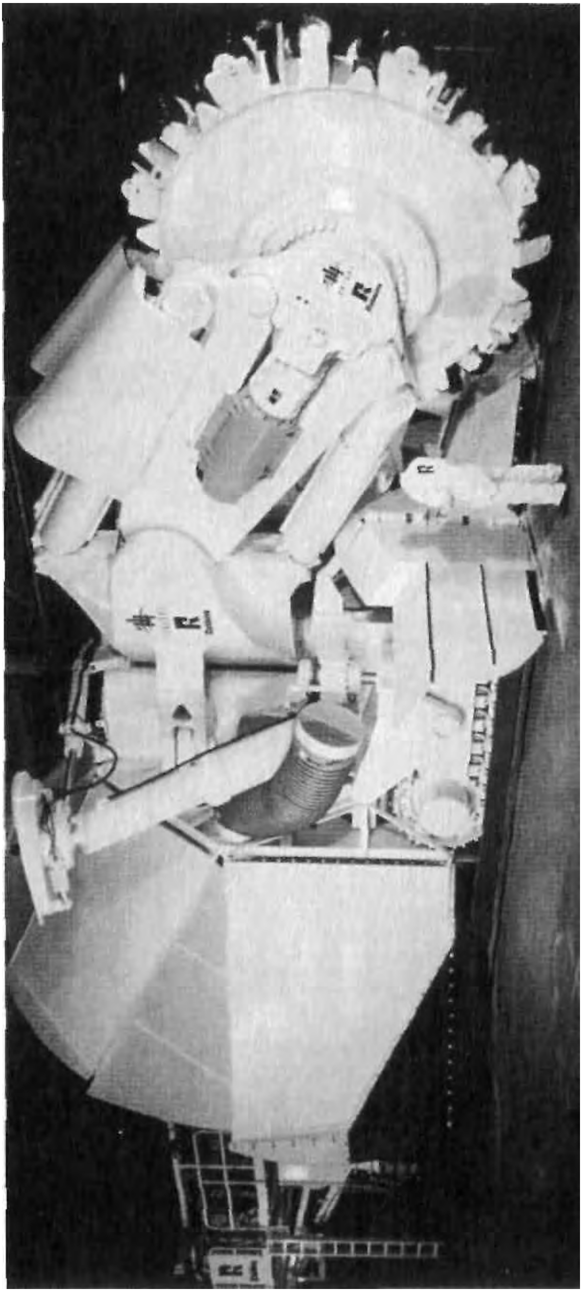


ILLUSTRATION 31 -This Mobile Miner, sold by The Robbins Company, cuts a large D-shaped tunnel. Photo used with permission from The Robbins Company.

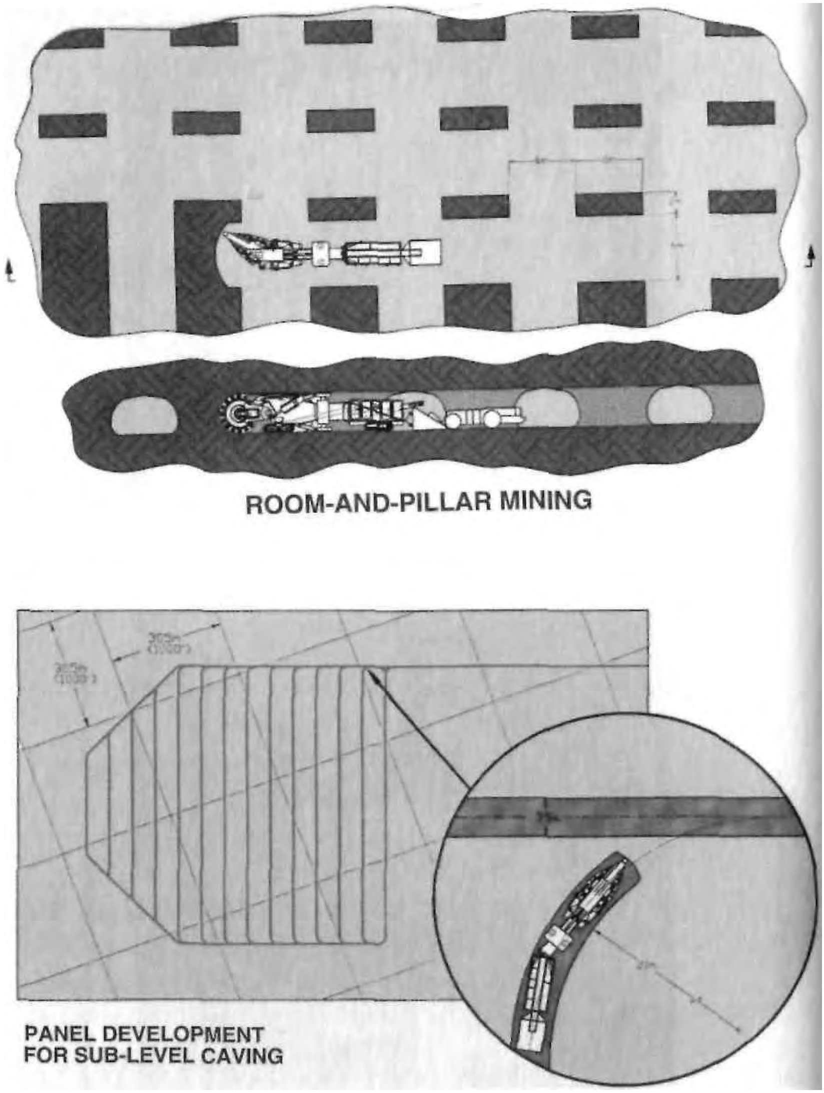


ILLUSTRATION 32 - Depiction of a Robbins Company Mobile Miner in action. The sales literature promises "high advance rates ..." and"... high speed tunneling ..." The large area under excavation in the diagram is amazing; each of the grids in the lower figure is 1,000 ft. on a side. Photo used with permission from The Robbins Company.

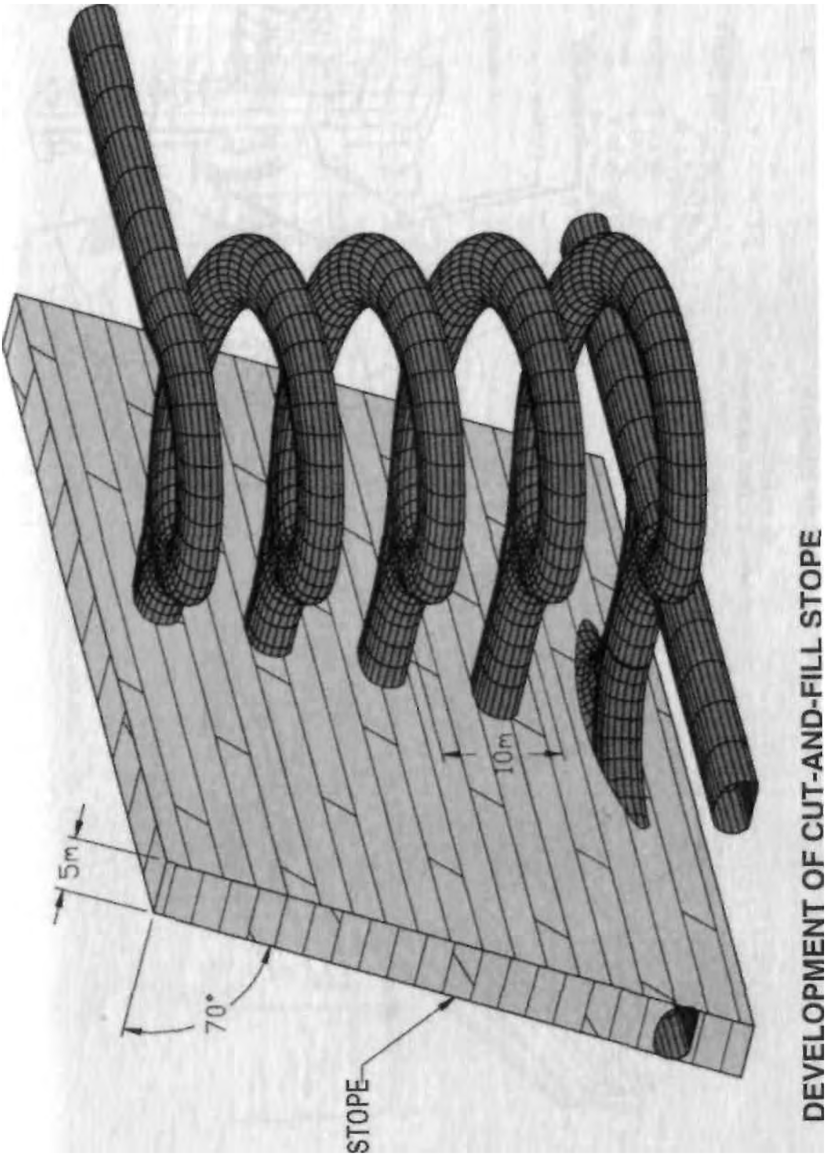


ILLUSTRATION 33 - The Mobile Miner can cut this kind of access tunnel, which is over 15 feet wide. Photo used with permission from The Robbins Company.

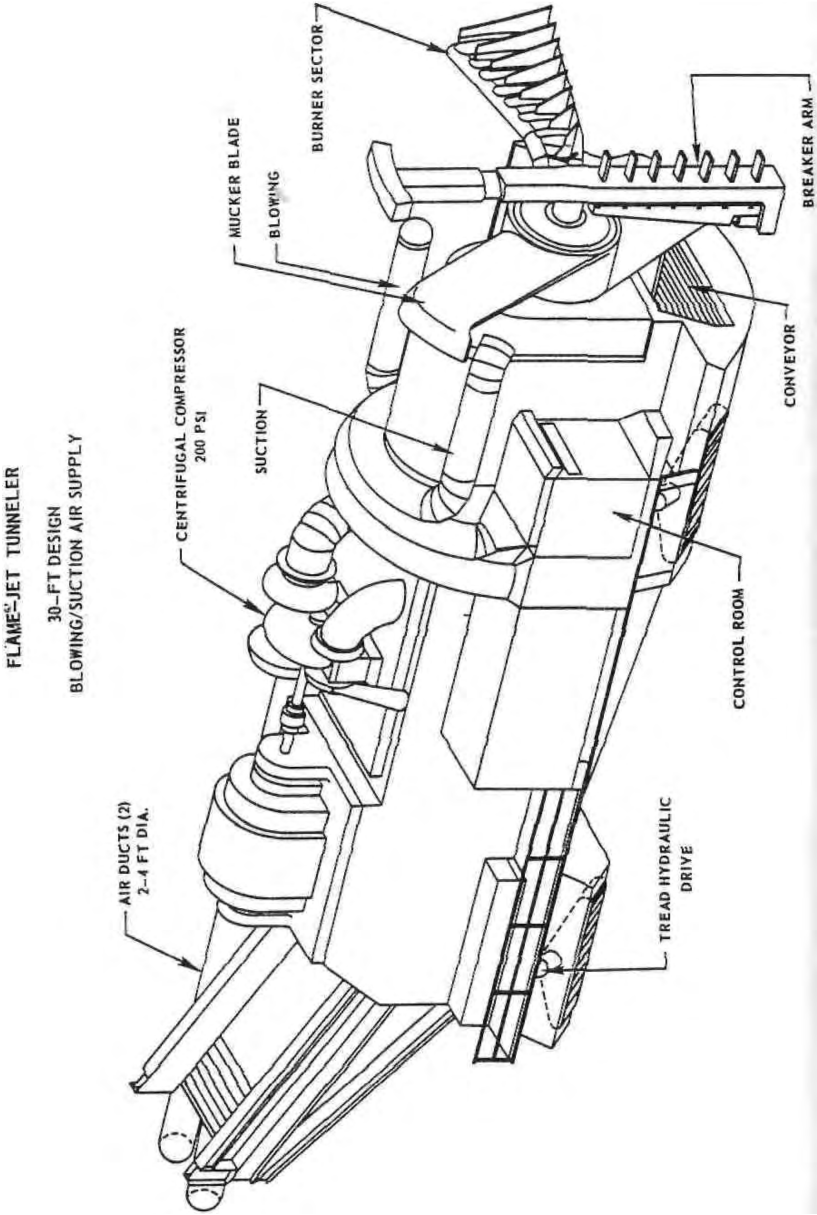


ILLUSTRATION 34 - A Flame Jet Tunneler, as pictured by the U.S. Dept. of Transportation, Office of High Speed Ground Transportation. From Feasibility of Flame-Jet Tunneling. Volume II-Systems Analysis and Experimental Investigations (May 1968), Fed. Doc. No. PB-178199.

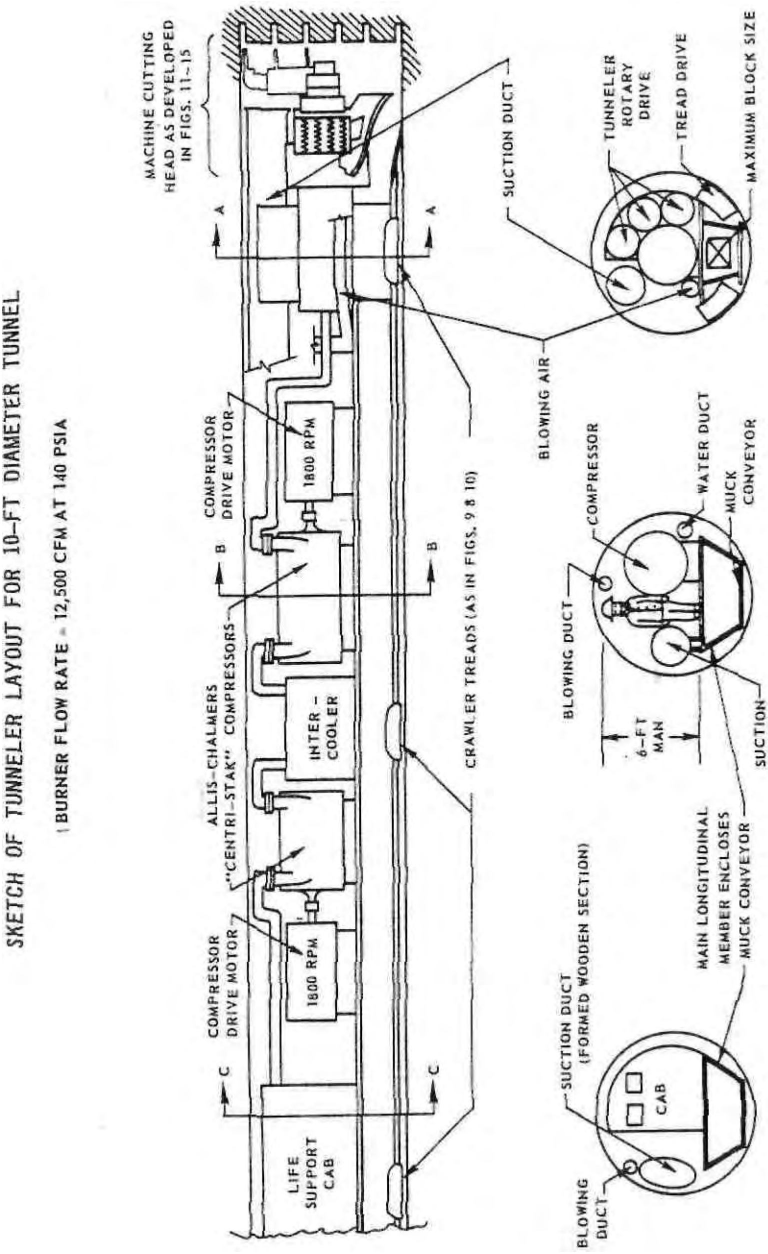


ILLUSTRATION 35 - A Flame Jet Tunneler, as pictured in cross-section by the U.S. Dept. of Transportation, Office of High Speed Ground Transportation. From Feasibility of Flame-Jet Tunneling. Volume II - Systems Analysis and Experimental Investigations (May 1968), Fed. Doc. No. PB-178199.

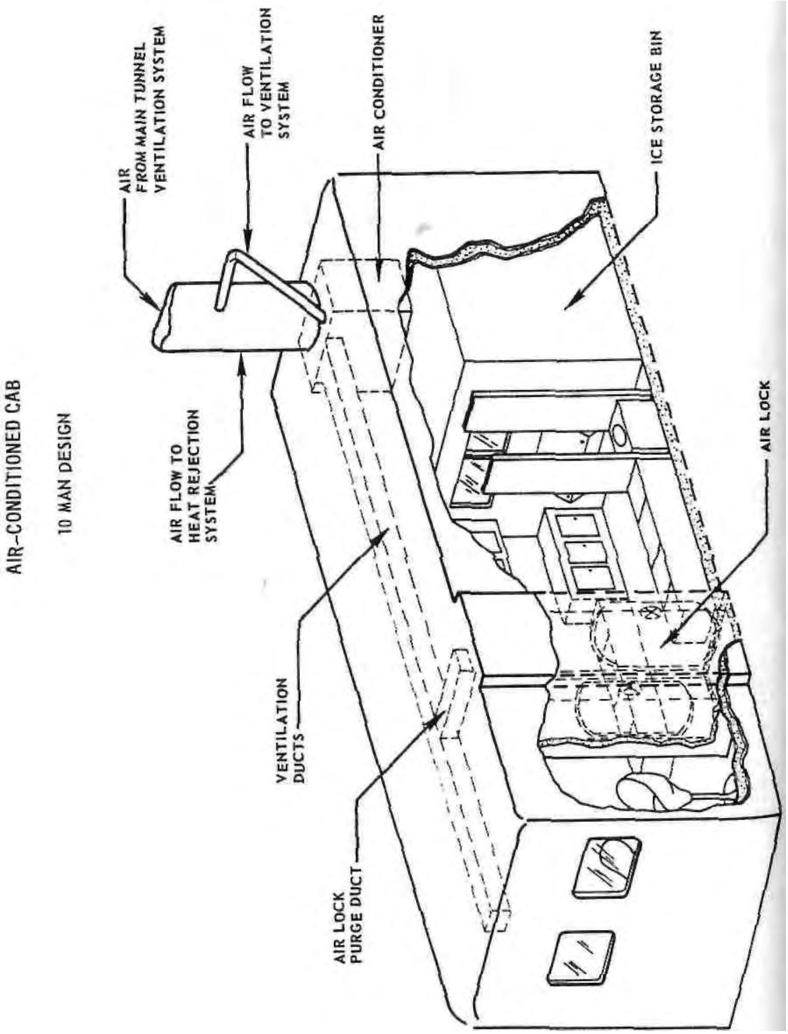


ILLUSTRATION 36 - The air-conditioned cab, capacity 10 men, in a Flame Jet Tunneler, as pictured in cross-section by the U.S. Dept. of Transportation, Office of High Speed Ground Transportation. The heat generated by the cutting head of this machine would be intense, judging by the huge ice storage bin, air conditioning, and airlock. From Feasibility of Flame-Jet Tunneling. Volume II - Systems Analysis and Experimental Investigations (May 1968), Fed. Doc. No. PB-178199.

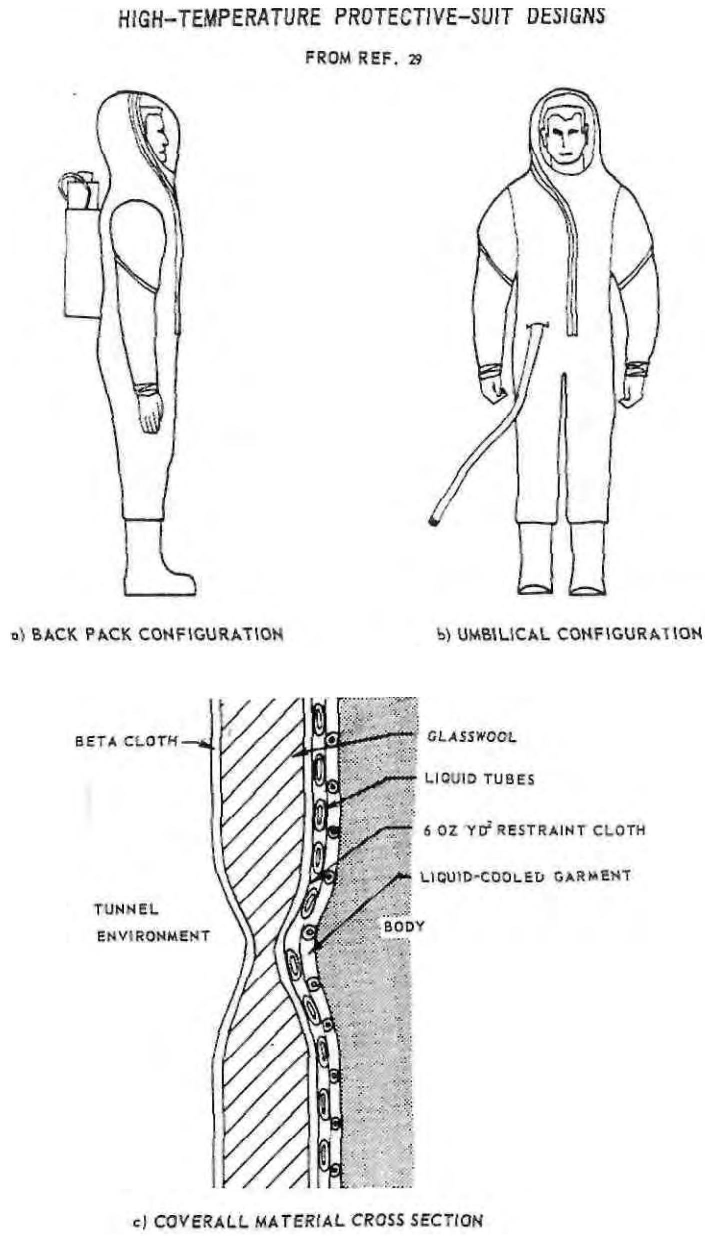


ILLUSTRATION 37 - Protective suiting for the operators of the Flame Jet Tunnelers. The umbilical cords hook up to an elaborate cooling apparatus (not shown here). From Feasibility of Flame-Jet Tunneling, Volume II - Systems Analysis and Experimental Investigations (May 1968), Fed. Doc. No. PB-178199.

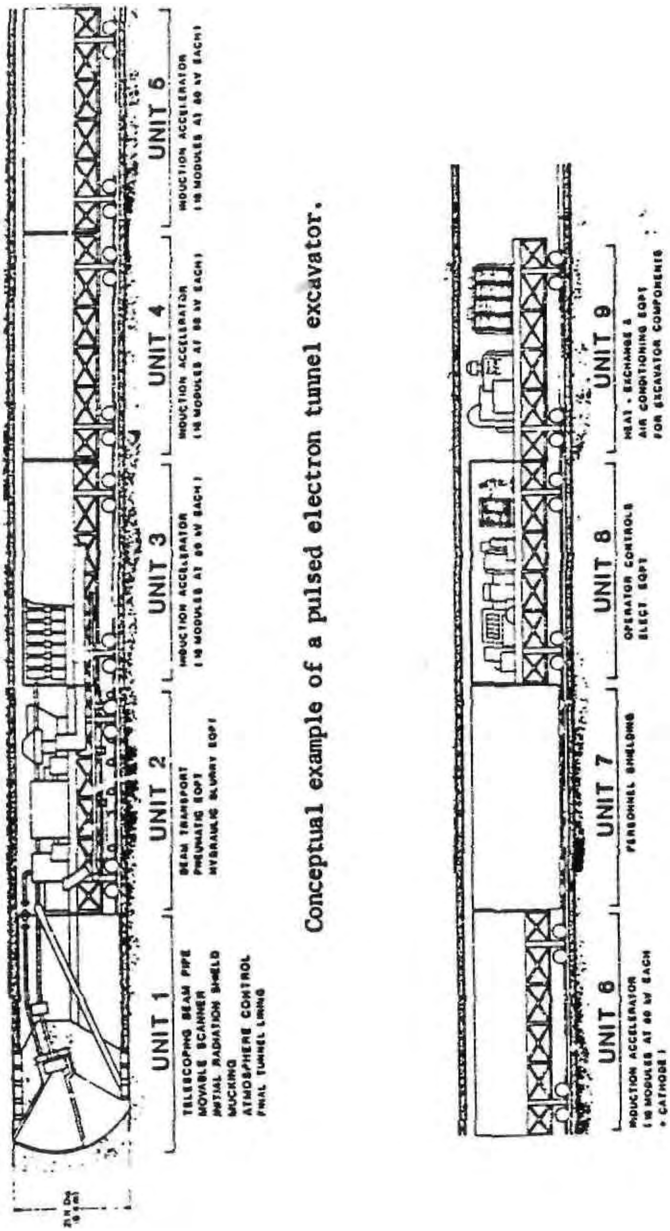


ILLUSTRATION 38 - A conceptual drawing of a hard rock tunneling machine that uses pulsed electron beams to cut the rock. To fit this illustration on one page, the drawing was cut between Unit 5 and Unit 6; in the original, the whole machine forms one linked set of cars. From Accelerat or Division Annual Reports, 1 July 1972-31 December 1974. Fed. Doc. No. LBL-3835, UC-28 Particle Accelerators, TID-4500-R62.

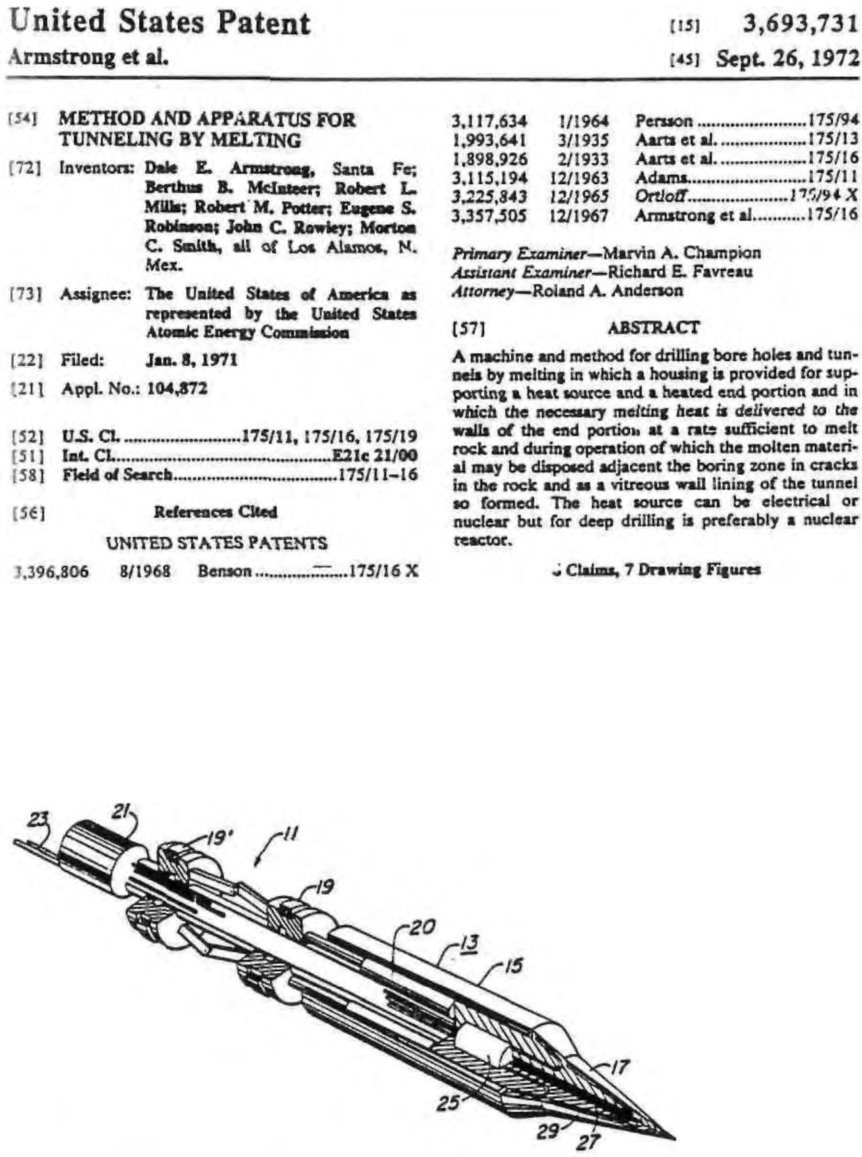


ILLUSTRATION 39 - A nuclear-powered tunneling machine patented by the United States of America, represented by the U.S. Atomic Energy Commission. This tunneler is designed to convert the rock that it excavates into a molten liquid, which fills cracks in the rock, bonds to the walls of the tunnel, and leaves behind a smooth, vitreous lining. The United States Patent Office issued the patent on 26 September 1972.

United States Patent [19] [11] **3,881,777**

Altseimer et al. [45] **May 6, 1975**

[54] **APPARATUS AND METHOD FOR LARGE TUNNEL EXCAVATION IN SOFT AND INCOMPETENT ROCK OR GROUND**

[75] Inventors: **John H. Altseimer; Robert J. Hanold**, both of Los Alamos, N. Mex.

[73] Assignee: **The United States of America as represented by the United States Energy Research and Development Administration**, Washington, D.C.

[22] Filed: **Jan. 25, 1974**

[21] Appl. No.: **436,402**

[52] **U.S. Cl.** **299/33; 175/11; 176/DIG. 3; 299/14**

[51] **Int. Cl.** **E21c 9/04**

[58] **Field of Search** .... *299/33, 14; 175/11, 16;* **61/45 R**

[56] **References Cited**

UNITED STATES PATENTS

3,334,945	8/1967	Bartlett	299/33
3,396,806	8/1968	Benson	175/11
3,667,808	6/1972	Tabor	299/33
3,693,731	9/1972	Armstrong et al.	175/11

Primary Examiner—Frank C. Abbott
Assistant Examiner—William F. Pate, III
Attorney, Agent, or Firm—John A. Horan; Henry Heyman

[57] **ABSTRACT**

A tunneling machine for producing large tunnels in soft rock or wet, clayey, unconsolidated or bouldery earth by simultaneously detaching the tunnel core by thermal melting a boundary kerf into the tunnel face and forming a supporting excavation wall liner by deflecting the molten materials against the excavation walls to provide, when solidified, a continuous wall supporting liner, and detaching the tunnel face circumscribed by the kerf with powered mechanical earth detachment means and in which the heat required for melting the kerf and liner material is provided by a compact nuclear reactor.

The invention described herein was made in the course of, or under a contract with the U. S. ATOMIC ENERGY COMMISSION.

3 Claims, 5 Drawing Figures

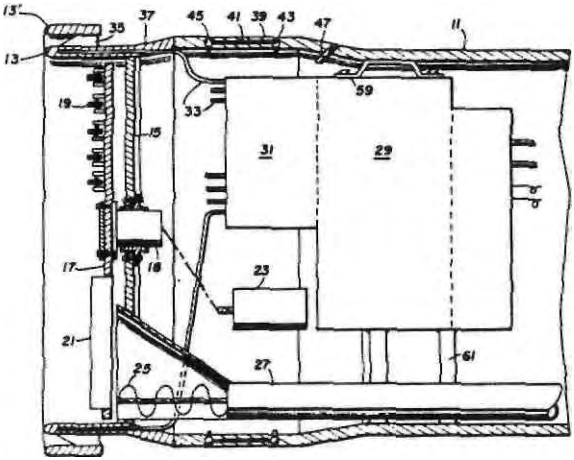


ILLUSTRATION 40 - Another nuclear-powered tunneling machine patented by the United States of America, this time represented by the U.S. Energy Research and Development Administration. The United States Patent Office issued the patent papers on 6 May 1975.

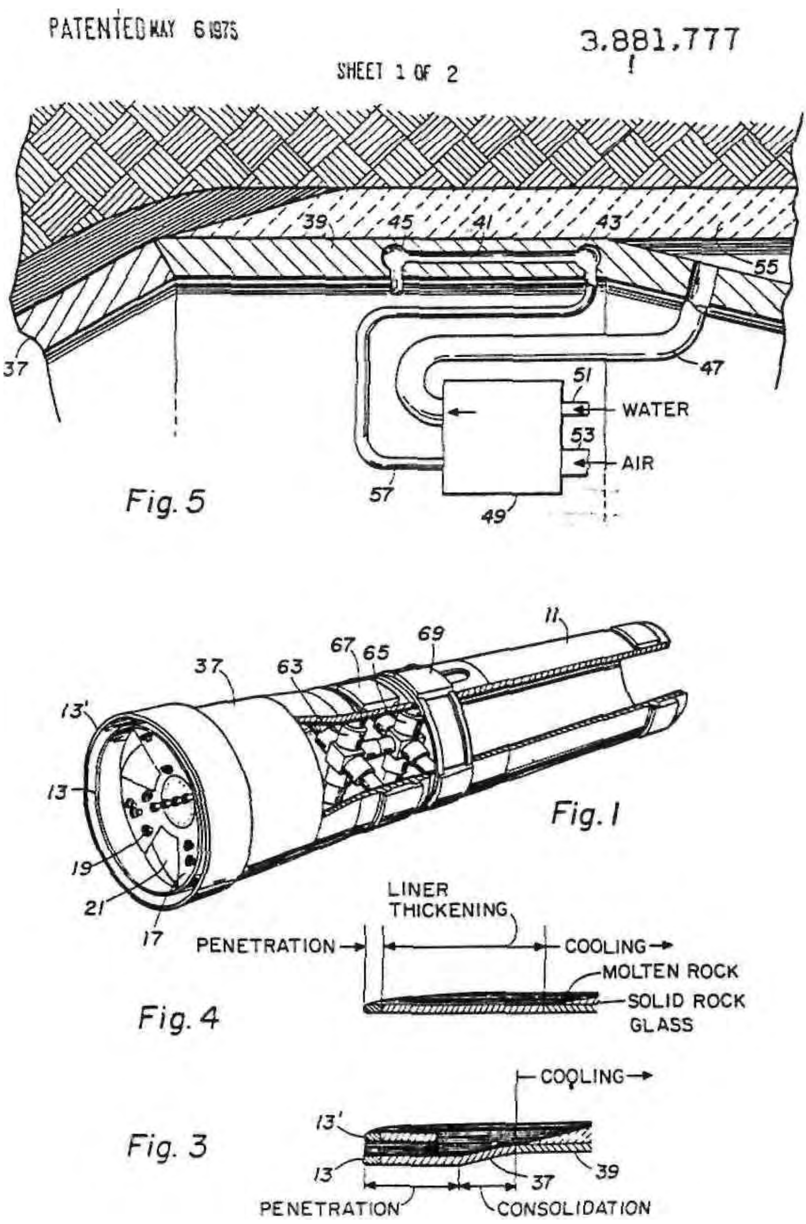


ILLUSTRATION 41 - Another page of drawings from the 6 May 1975 patent for a nuclear-powered tunneling machine, granted to Los Alamos, New Mexico inventors working for the U.S. Energy Research and Development Administration. This machine would leave behind neat, glass-lined tunnels.

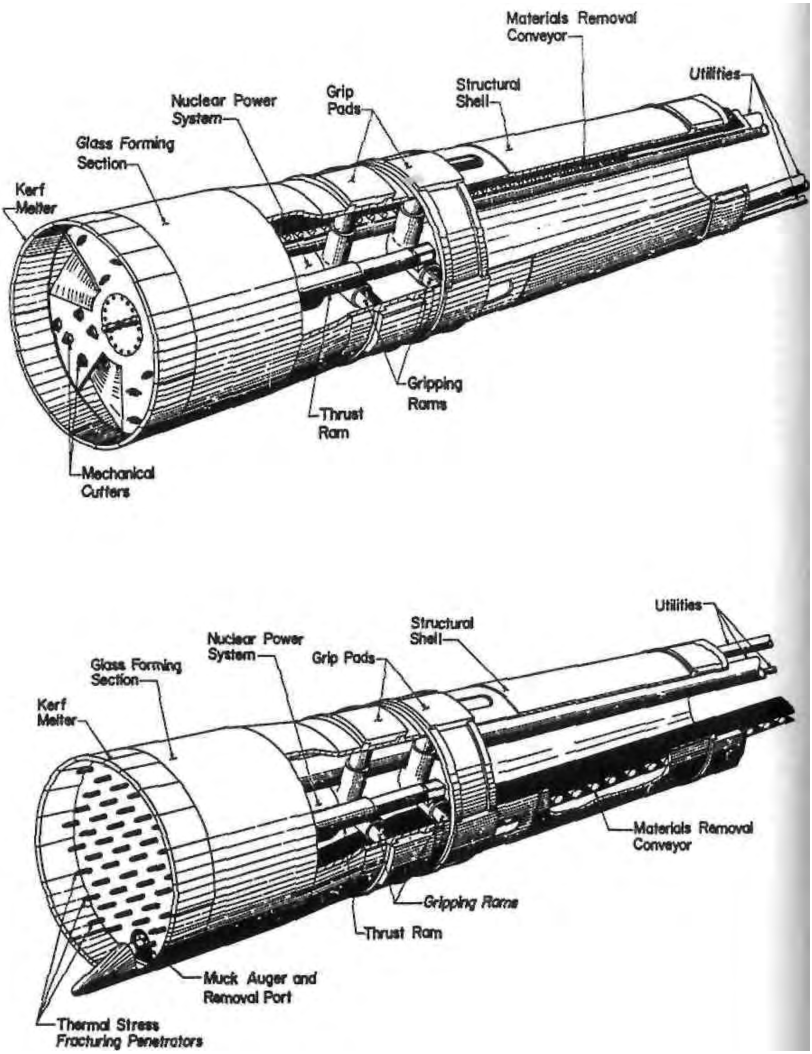


ILLUSTRATION 42 - Two different types of Nuclear Subterrene Tunnel Boring Machines. These machines are designed to melt their way through the rock and soil, leaving behind neat, glass lined tunnels. Source: Large Suberrene Rock-Melting Tunnel Excavation Systems: A Preliminary Study. Fed. Doc. No. LA-5210-MS.

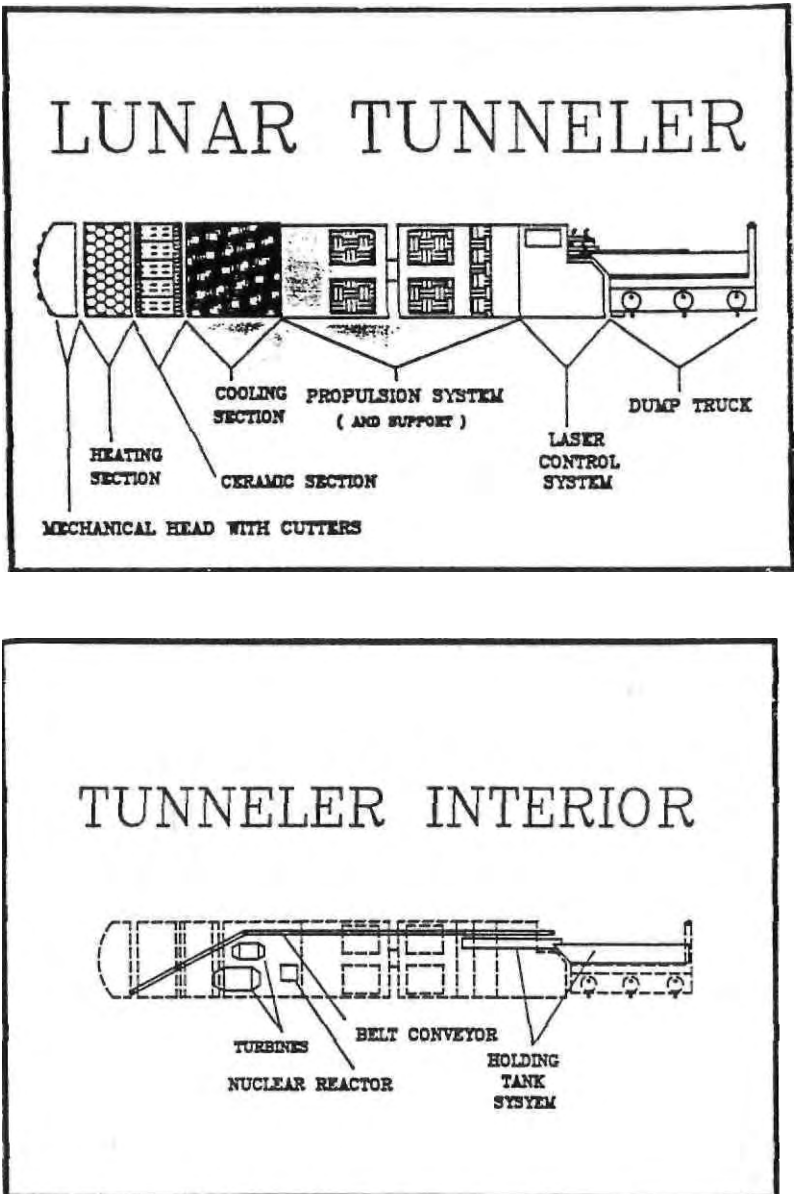


FIGURE 21: EXCAVATION CONCEPT

ILLUSTRATION 43 - A Lunar Tunneler, as proposed in a project funded by a grant from NASA/USRA. Reprinted with permission from Proposal for a Lunar Tumid-boring Machine, by Allen, Cooper, Davila, Mahendra and Tagaras, report presented to Prof. Stan Lowy, Dept. of Aerospace Engineering, Texas A&M University (5 May 1988).

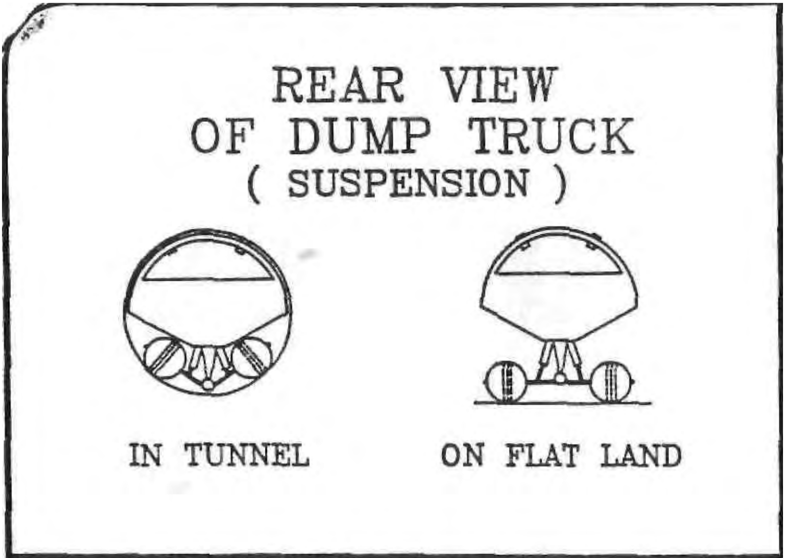


FIGURE 25: DUMP TRUCK SUSPENSION

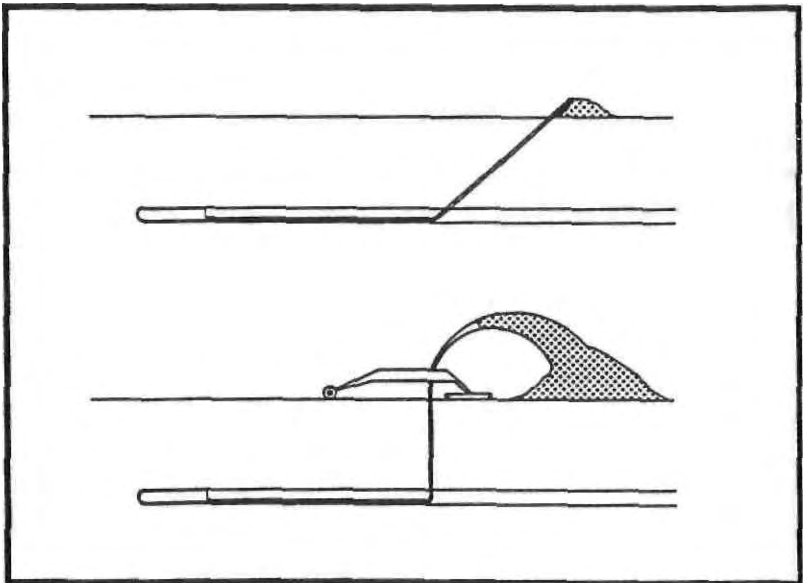
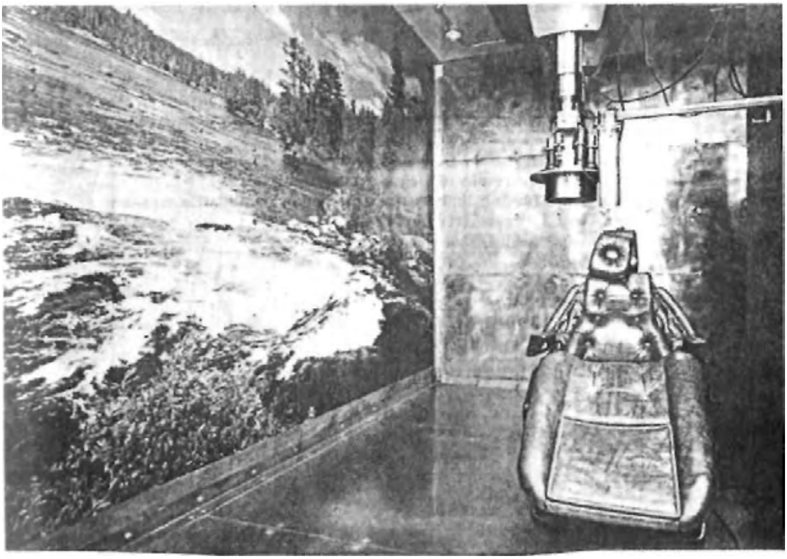


FIGURE 20: EXCAVATION SYSTEMS

ILLUSTRATION 44 - The dumping process from the Lunar Tunneler proposal. In the bottom drawing, excavated lunar soil is sprayed into a large pile by a movable car. Reprinted with permission from Proposal for a Lunar Tunnel-boring Machine. by Allen, Cooper, Davila, Mahendra and Tagaras, report presented to Prof. Stan Lowy, Dept. of Aerospace Engineering, Texas A&M University (5 May 1988).



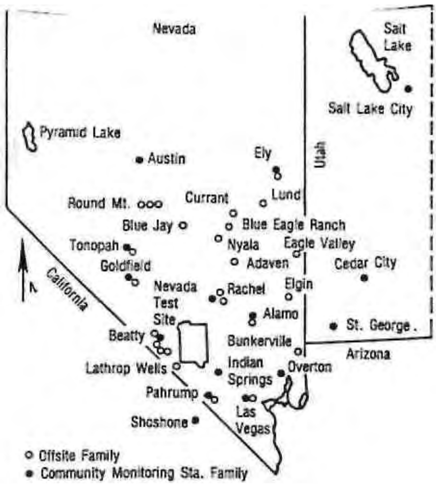


ILLUSTRATION 45 - The Environmental Protection Agency tracks the migration of atomic particles from the Nevada Test Site into the animals and humans of the surrounding environment. This map, modified from an EPAmap, shows the location of about 40 families who are brought into the EPA twice a year for whole-body analysis. Part of their examination takes place in the reclining chair pictured in the photograph. The machinery which hangs from the ceiling performs a whole-body scan of the subject. Source: U.S. Congress, Office of Technology Assessment, The Containment of UndergroundNuclear Explosions, OTA-ISC-414 (Washington, DC: US Government Printing Office, October 1989).

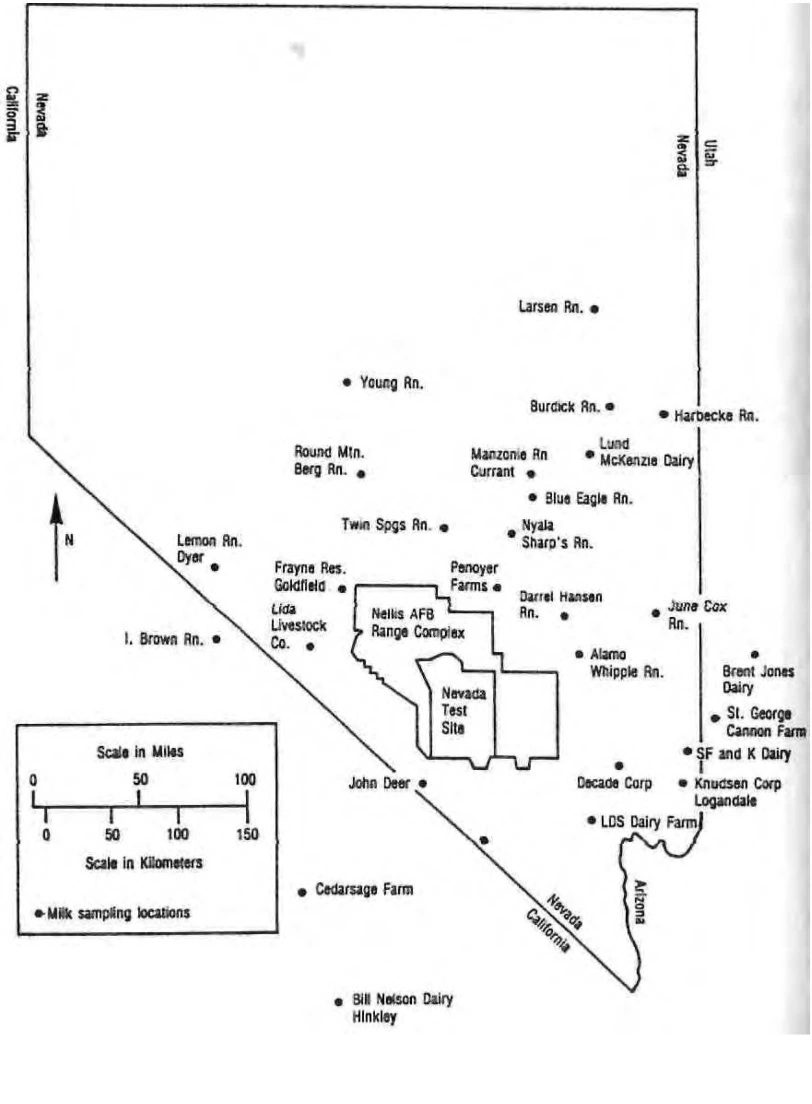


ILLUSTRATION 46 - Samples of raw milk are collected each month from about 25 farms surrounding the Nevada Test Site. Source: U.S. Congress, Office of Technology Assessment, The Containment of Underground Nuclear Explosions, OTA-ISC-414 (Washington, DC: US Government Printing Office, October 1989).

ILLUSTRATION 47 - Is the government more concerned about nuclear pollution of the environment than it lets on? Every year it collects milk samples for analysis from its standby milk surveillance network, which is made up of all of the major milksheds west of the Mississippi River. Source: U.S. Congress, Office of Technology Assessment, The Containment of Underground Nuclear Explosions. OTA-ISC-414 (Washington, DC: US Government Printing Office, October 1989).

United States Patent [19]

Milheiser

[11] **Patent Number:** **5,166,676**

[45] **Date of Patent:** **Nov. 24, 1992**

[54] IDENTIFICATION SYSTEM

[75] Inventor: **Thomas A. Milheiser**, Littleton, Colo.

[73] Assignee: **Destron/IDI, Inc.**, Boulder, Colo.

[21] Appl. No.: **484,458**

[22] Filed: **Feb. 16, 1990**

Related U.S. Application Data

[60] Continuation of Ser. No. 388,761, Aug. 2, 1989, abandoned, which is a continuation of Ser. No. 165,310, Mar. 8, 1988, abandoned, which is a division of Ser. No. 814,492, Dec. 30, 1985, Pat. No. 4,730,188, which is a continuation of Ser. No. 580,401, Feb. 15, 1984, abandoned.

[51] **Int. Cl.**[5] **H04Q 1/00**
[52] **U.S. Cl.** **340/825.540**; 340/825.34
[58] **Field of Search** 340/825.54, 825.55, 340/825.69, 825.72, 825.34, 825.94, 572; 455/118, 41; 375/45, 46, 62, 49; 370/53

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,022,492	2/1962	Kleist et al.	340/825.54 X
3,137,847	6/1964	Kleist	340/825.69 X
3,689,885	9/1972	Kaplan et al.	455/41 X
3,890,581	6/1975	Stuart et al.	375/62 X
3,898,619	8/1975	Carsten et al.	340/572 X
4,114,151	9/1978	Denne et al.	
4,129,855	12/1978	Rodrian	340/825.54
4,287,596	9/1981	Chari	375/49
4,313,033	1/1982	Walker et al.	370/53
4,333,073	6/1982	Beigel	340/825.54
4,368,439	1/1983	Shibuya et al.	375/62 X
4,388,524	6/1983	Walton	340/825.72 X

OTHER PUBLICATIONS

Ray Ryan "Basic Digital Electronics", Tab Books, Blue Ridge Summit, Pa. pp. 52–55, 1975.

Primary Examiner—Ulysses Weldon
Attorney, Agent, or Firm—Earl C. Hancock; Francis A. Sirr

[57] **ABSTRACT**

A passive integrated transponder (PIT) is attached to or embedded in an item to be identified. It is excited via an inductive coupling from an interrogator. The PIT responds to the interrogator via the inductive coupling with a signal constituting a stream of data unique to the identified item. The signal is in the form of two different frequencies, a shift from one frequency to the second during a bit cell representing a data "one", and a shift from the second frequency to the first frequency representing a data "zero". The responsive signal is then detected and processed for utilization in a data storage or display device.

10 Claims, 7 Drawing Sheets

BACKGROUND AND OBJECTS OF THE INVENTION

The primary object of this invention is to provide a system for identifying an object, animal or person consisting essentially of two units, one being a passive integrated transponder (PIT) which is carried by or embedded in the thing or animal to be identified and which responds to interrogation with an identifying code, and the other unit being an interrogator-reader separate from the PIT.

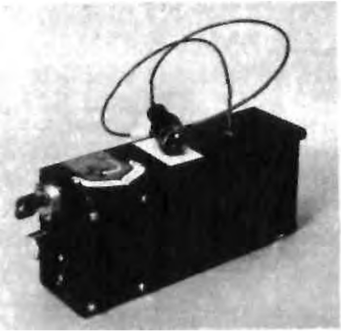
Heretofore, in identification device systems, there is

ILLUSTRATION 48 - This U.S. patent describes the inner electronic workings of an injectable transponder. Note the detail from this patent, which says 'The primary object of this invention is to provide a system for identifying an object, animal of person..." More than one company in the U.S. now sells injectable electronic IDs They are commonly used to identify livestock or companion animals.

Fact Sheet

United States Air Force
AIR FORCE MATERIEL COMMAND
Office of Public Affairs, Phillips Laboratory
3550 Aberdeen Ave SE, Kirtland AFB, NM 87117-5776
(505)846-1911

LASER MEDICAL PAC



The Laser Medical Pac, being developed in-house by the USAFs Phillips Laboratory, is a very compact device that provides the field paramedic or physician a unique, portable, and battery-operated laser capability. The laser is able to cut like a scalpel, as well as coagulate bleeding, and close wounds.

The Laser Medical Pac has military applications for advanced trauma life support on the battlefield. It can be used by special operations personnel, pararescue jumpers, squadron medical elements, and flight surgeons. Civilian uses for the Pac are in stabilizing highway accident victims before they are transported to a hospital.

The laser component is now commercially available. The commercial variety, however, requires an electrical power hookup.

The Phillips Laboratory system consists of a completely self-contained laser package that fits inside a beltpack. Laser energy is delivered to the instrument by a fiber-optic cable, the fiber providing very intense power density at the tip of the instrument. The output wavelength, which ranges from visible red to the mid-infrared, can be designed to provide different tissue interactions.

The Pac is powered by two 2-volt batteries to operate the laser and one 9-volt battery to power the electronics. It features a unique phase change heat sink that allows 20 minutes of continuous operation. (Under normal usage the heat capacity should allow unlimited thermal capacity.) The laser is protected against over-temperature by a thermal switch. A battery recharger port is also provided, as is a key lock for safety and security reasons. The fiber-optic is pig-tailed into the laser array and "pipes" the laser light to the variable focus lens. The light at the tip of the fiber is very intense (one kilowatt per square centimeter).

-MORE-

ILLUSTRATION 49 - This medical laser is portable enough to be worn on a belt pack around the waist, and can be used to either make cuts or close wounds. According to the Air Force, "It can be used by special operations personnel..." Reprinted with permission from Phillips Laboratory, Office of Public Affairs, Kirtland Air Force Base, NM.

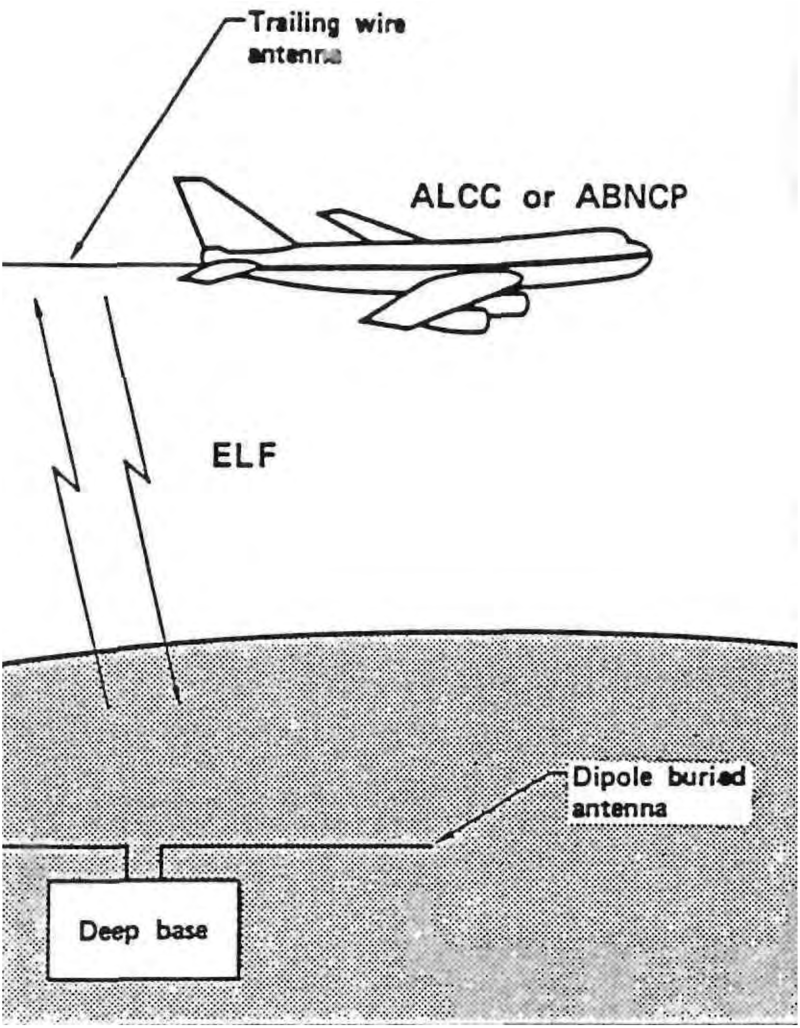


ILLUSTRATION 50 - Communication from a deep underground base could transmit through conventional ground lines; through a satellite or microwave dish; or ~ as this illustration shows ~ in a way that would be invisible to a surface observer. Extremely Low Frequency (ELF) communications transmit through the earth itself, using a widely-spread underground antenna system. Source: Decision Analysis Methodology Applied to Deep Base Communications, Subtask Progress Report for 1985 Prepared for the Headquarters, Ballistic Missile Office, USAF. Document ID Nos.-.AFMIPR No. FY 7653-85-00305; UCID - 20848; and DE87 000945.

and other flaky characters, and nothing more. In that way, the Pentagon could carry out its underground agenda and prying eyes would be deflected by the threat of public humiliation and ridicule.

In any event, the evidence I have presented above is the closest I can come to documenting an actual, covert, underground tunnel system in the western states. This system may or may not exist.

The Department of Transportation Tunnel Plans

I have found less documentation for the Department of Transportation's planned tunnel system in the Northeast. I was able to find a few documents, however, including one lengthy report that spoke forthrightly about constructing what it referred to as a "High Speed Ground Transportation (HSGT) system in the Northeast Corridor." Presumably the system would be for the use of commuters, although just who would use the tunnels was left somewhat ambiguous. Vague reference to "vehicles" that would use the system also left some doubt as to the mode of transportation that was to have been employed. In the following chapter on unconventional tunneling technologies I present documentation on a flame-jet tunneling system intended for constructing a deeply buried, high speed rail tunnel system in the Northeast. These two sets of documents would appear to be describing plans for one and the same system, the more so since they were both published in the same year (1968).

As set forth in the document, the tunnel system could have ranged as deeply as 3,500 ft. underground. It was to have been at least 500 ft. underground when cutting beneath major rivers, with the exception of the Hudson, under which it was to cross at a depth of not less than 750 ft. Diameters for tunnels in the system were not specified,

though a range of excavated diameters (not to be confused with finished diameters, which would be somewhat less due to the tunnel lining and support) all the way from 8 ft. to 40 ft. was discussed. Specifically, diameters of 8 ft., 20 ft., 30 ft. and 40 ft. were mentioned.

An obvious question is: why would the DOT bother to construct an inter-city tunnel system that would be less than 8 ft. in diameter? It hardly makes sense, except as an auxiliary or utility tunnel for a larger diameter companion tunnel. The larger diameters, of course, could conceivably accomodate some sort of rapid rail, or magnetic levitation train.[16]

Terminals were to range in size between 10,000 and 1,000,000 sq ft. in area, and to have multiple levels. They were slated to be located at least 300 ft., and in some cases, 500 ft. or more underground. They were to have been as much as 2,000 ft. long.

The terminals were to have been situated under or near: Washington, DC; Baltimore, Maryland; Philadelphia, Pennsylvania; New York, New York; New Haven, Connecticut; Hartford, Connecticut; and Boston, Massachusetts. The plans also called for at least one deep shaft between each city to connect with the system. The shafts were to be vertical, and quite large and deep -- extending as far down as 3,500 ft., if necessary, and having a cross-section of between 50 and 500 sq. ft.[17]

Plans vs. Real Tunnels

Once again, the question arises: has this system been built? The planning study is certainly very interesting. In fact, it is just the sort of obscure document you would expect to find if, indeed, a secret tunnel system were being planned and/or built by the U.S. government.

But the reader must be clear on the fact that plans are one thing, and actual tunnels quite another. Sometimes plans culminate in completed construction projects; at other times, plans are never concretely realized and are relegated instead to a dusty shelf in the government documents collection.

I simply do not know if the government (or some other organization) has secretly built a high speed transportation tunnel system in the northeastern corridor of the United States. If you do, please send me the relevant documentation.

Chapter Six

TUNNELLING MACHINES (THE CONVENTIONAL TYPES AND THE SCIENCE FICTION "BLACK" MODELS)

As strange as some of the information that I've presented so far may seem, some of the tunneling machine plans discussed in this chapter are stranger still.

The first thing to understand is that there are actual tunnelling machines that crawl through the ground like giant mechanical earthworms with huge appetites. These tunneling machines are used on construction projects all over the world to build perfectly ordinary sewers, subways, utility lines, highways, railroads, aquaducts, hydroelectric projects -- as well as jazzy, high-profile projects like the "Chunnel", the tunnel underneath the English Channel that now makes it possible to travel on dry ground between England and France.

As for other, more bizarre tunnel systems and tunnel boring machines that are rumored to exist, the best that I can do is to present for your consideration in this chapter new and fascinating information that most readers probably have never seen before. At the least, I think the evidence that is set out in the following pages is intriguing and suggestive.

The discussion begins with the "conventional" machinery - which you may, nevertheless, find surprising.

Conventional Tunnel Boring Machines (TBMs)

Conventional Tunnel Boring Machines (or TBMs, as they are known in the trade) are huge, cylindrical, mechanical boring machines that tunnel through the rock and soil, chewing out circular tunnels that may range in diameter up to 35 ft. or more (See Illustrations 28 and 29). Conventional rock tunnelling TBMs are powered by electrical motors and have a cutting head, equipped with various metal attachments made of superhard alloys that cut the rock as the head rotates. The head rotates and the cutting tools dig into the rock; ripping and gouging it away. The excavated rock ("muck") is then passed back by a conveyor assembly to the rear of the machine, where it can be hauled away by truck or train.

The tunneling machine braces itself against the walls of the tunnel section it has just bored by means of powerful, hydraulic gripper pads. Other hydraulic jacks thrust the cutter head forward, against the face of the tunnel. When the cutter head is extended as far forward as the thrust jacks permit, the gripper pads are retracted, the machine is advanced forward against the face of the tunnel, the side gripper pads are again extended to lock the body of the machine solidly in place in the tunnel, and the thrust jacks again apply pressure to the cutter head, as it once again begins to grind and tear away at the tunnel face, boring its way through the rock. In brief, that is how a conventional tunnel boring machine works.[1]

The entire assembly, including cutting head, motors, transformers, hydraulic systems, mucking system and conveyors can be up to one hundred feet long or more, as the illustrations show.

The machine may be shielded, to keep rock and debris from falling in on the crew or to prevent tunnel collapse, until a protective tunnel lining can be put in place. Such a

tunnel lining is commonly made of concrete or steel bracing. If the rock is stable enough, however, it may not be necessary to install a lining. Oftentimes rock bolts are used to stabilize the tunnel walls and roof. These are simply long steel rods, threaded on the end, that are screwed or driven into the rock, and which anchor small, flat, steel plates against the wall or roof of the tunnel (See Illustration 14). In this way, the rock bolts lend structural support to weak rock and help prevent rock falls and the like.

Over the last 35 years many of these tunnel-making machines have been produced. They have been used to construct utility conduits, highways, railroads, aquaducts, hydroelectric projects, subways, and more. There is an enormous amount of tunneling activity going on around the world, and most of it is perfectly straightforward, for legitimate purposes. A few of the companies that have manufactured TBMs are: (a) The Robbins Company of Kent, Washington; (b) Jarva Incorporated; (c) The Lawrence Division of the Ingersoll Rand Company; (d) The Hughes Tool Company; (e) Dresser Industries; (f) The Wirth Corporation (a German company); and (g) Atlas Copco.[2]

Many companies have built tunneling machines, but my research shows the Robbins Company to be far and away the leading manufacturer of tunnel boring equipment -- and, in fact, the Robbins Company promotes itself in sales materials as the foremost tunneling firm in the world. Robbins has been in business since the 1950s and has made many of the conventional TBMs in use. In 1993, The Robbins Company merged with Atlas Copco Mechanical Rock Excavation; the new business is known as "The Robbins Company: A company in the Atlas Copco Group". Promotional literature from the new Robbins Company

says, "The next TBM we build for you, whether Robbins or Jarva, will be the best you have ever bought." All of the TBMs in Illustrations 28 and 29 were built by Robbins. That is not to say that other companies are not involved with tunneling projects, because they are.

For projects requiring a huge shaft bored straight down into the earth (and some of the projects described in this book call for vertical shafts), the Robbins Company manufactures the appropriate machinery (See Illustration 30).

In the Arnold Schwarzennegger movie, Total Recall, about a futuristic, CIA-operated mining colony on Mars, tunneling and mining machines were depicted that somewhat resemble machines that are already in actual use right here on Earth. These machines are called roadheaders, and mobile miners.[3] See Illustrations 31-33 for a Robbins mobile miner, and the kind of tunnels that it is capable of excavating. Robbins prides itself on the rapidity with which these types of machines operate. The brochure from which these illustrations are taken boasts: "The high advance rates of tunnel boring machines are well documented. ... the Mobile Miner can provide continuous, rapid advance of headings, and can create ideal cross-sections for the safe and rapid transportation of men and equipment underground. The flexibility and maneuverability of the Mobile Miner provide high speed tunneling..."

Consider the size of the field in which the mobile miner is depicted as operating in Illustration 32: each of the square grids is 1,000 feet wide; the whole area is over a mile wide. Look at the beautiful dowward-spiralling tunnel in Illustration 33; the width of the tunnel is about 15 feet. That's wide enough for two average-size cars to pass one another.

This is what industry is capable of doing right now, and it is impressive.

Drill and Blast Method

Before moving on to discuss nonconventional tunnel boring technologies I want to mention one other conventional method of tunneling, the drill and blast method. It has been used for a couple of centuries or more (mostly in hard rock mining) and its very name describes the method well.

Holes are drilled in the tunnel face; explosives are placed in the holes; the explosives are detonated; the rock disintegrates under the force of the explosion; and the disintegrated rock (muck) is removed by front end loaders to trucks, or other conveyors, such as narrow gauge trains, which cart away the debris. This cycle is repeated over and over again to lengthen the tunnel until the job is completed. There is nothing magical about this process. Any miner will tell you that it simply entails a lot of difficult, dangerous work.

No doubt much of the underground construction for the facilities mentioned in this report has been accomplished using the drill and blast method. While not glamorous, underground drilling and blasting is a time-proven, sure-fire way to excavate underground tunnels and chambers. It is a known technology and it works. All of the myriad mining companies in the United States and around the world use this technique every day to mine everything from coal, to copper, iron, salt, uranium, tin, gold, silver and lead.

In other words, there is a huge pool of workers in the United States alone who have experience in the mining industry and who have tunneled or excavated underground using drill and blast techniques. This author, for instance,

was once employed by Morton Salt and actually worked for a brief period on the powder crew in a salt mine 800 ft. underground, drilling and blasting out huge caverns in the rock salt.

I can assure you that there is a ready supply of experienced labor that could easily be tapped for covert mining, tunneling and excavation projects -- especially the kinds that pay good government wages!

Nonconventional Tunneling Machines

Like many students of UFOlogy (and perhaps like some of the readers of this book) I have heard rumors in recent years of mythical TBMs that use lasers to bore their way through the rock.

As the stories run, these wondrous machines slice through the subterranean depths like a hot knife through butter, leaving neat, glass-walled tunnels in their wake. Although I have never seen one of these machines, or the glass-walled tunnels they allegedly make, I do not dismiss these stories out of hand.

As you are about to see, it is entirely conceivable that laser powered Tunnel Boring Machines, or equally exotic machines, have been developed and have been put to work on secret tunneling projects. I don't positively know that to be the case, but after reading what follows the serious student will have to admit that it is at least possible that a powerful new generation of nonconventional TBMs may have been developed and deployed - out of the public eye.

There Must Be 50 Ways To Dig a Tunnel

A 1974 RANN report from Bechtel[4] sets out a whole grocery list of technologies, techniques and apparatuses that could be used for underground tunneling or

excavation. They are all presented as "novel ground disintegration techniques," in an exploratory, research or developmental stage. As you will shortly see, though, at least some of these techniques may be a good deal more advanced than Bechtel was prepared to admit. This was probably as true in 1974, when Bechtel issued the report, as it is today. The techniques Bechtel listed were:

High Pressure Continuous Water Jet
Low Pressure Percussive Water Jet
Mechanically Assisted Continuous Water Jet
High Frequency Electrical Drill
Thermal Mechanical Fragmentation
Conical Borer
Turbine Drill
Pellet Drill
Spark Drill
Electric Arc Drills
Induction Drilling
Plasma
Microwaves
Jet Piercing Flame
Terra-Jetter
R.E.A.M.
Explosive Drill
Ultrasonic Drill
Hydraulic Rock Hammer
Subterrene
Water Cannon
Electrical Disintegration
Electron Beam Gun
Forced Flame
Lasers

Some of this stuff is straight out of Buck Rogers. There's no getting around the fact that the plain English translation of some of these entries is: ray gun. It does seem a bit far-fetched, but suppose there are actually machines that use these technologies tunneling away beneath our feet!

No matter whether it's science fiction fantasy or high-tech reality, this information comes straight out of an official government document. Here is a case where truth may yet prove to be as strange as any fiction!

The Already Strange Gets Even Stranger

Lest you think the 1974 Bechtel report to be beyond the pale, consider a 1971 article on tunnelling technology that contained the following entries:

• ITT Research Institute has just completed studies of the use of hyper-velocity fluid jets and pellet impact -- design of a high-velocity water cannon is underway and a prototype is planned for testing in 1972.
• United Aircraft Research Labs is studying use of a high-power pulsed laser mounted on a boring machine to weaken rock structures ahead of the cutter blades. If the study is successful, a prototype will be designed this year and then built for field testing in 1972.[5]

Water cannon ... laser ... both of these techniques were mentioned in the 1974 Bechtel report. And this report, from three years earlier, strongly suggests that the techniques were considered more than theoretically interesting. Plans for construction of working prototypes are specifically mentioned. Might these machines actually have been built?

Certainly interest in these exotic mining and excavation methods continued, because an article in the 1982 edition of an industry handbook[6] listed many of the same technologies again:

MECHANICAL: Water Cannon, Vibration, Abrasion, Cavitation, Pellet Impact

THERMAL: High-Velocity Flame, Flame Jet Cutting, Electric Arc, Electron Beam, Plasma, Freezing, Laser, Atomic Fusion

CHEMICAL: Softeners, Dissolvers

Again, most of these techniques are mentioned in the 1974 Bechtel report cited above. The techniques mentioned in the 1971 article discussed above also appear in this 1982 article.

The author of the 1982 article singles out the water cannon and flame jets as showing particular promise for tunneling machines. The water cannon essentially grinds away the rock face by directing a high-pressure, pulsed, water jet against it. Calweld and Exotech, Inc. are two companies mentioned in connection with development of water jet-assisted tunneling.

Flame jet tunneling uses very high temperature jets of flame to cut through the rock. United Aircraft Laboratories, cited above in connection with a partially laser powered tunneling machine, has done developmental work on flame jet tunneling.

Flame-Jet Tunneling

In a three-volume 1968 report, United Aircraft Research Laboratories presented a study of the feasibility of flame-jet tunneling. The report seems to have been stimulated by the professed desire of the U.S. Department of Transportation to find a more efficient means of tunneling so that it could construct a high speed, underground rail corridor in the northeastern part of the country. This appears to refer to the same, deep underground tunnel system discussed earlier in this report, which was to have connected the northeastern urban corridor between Washington, DC and Boston, Massachusetts. To my knowledge, an underground project fitting that description has never been carried out.

The flame-jet tunneler, as described by United Aircraft Research Laboratories, travels on crawler treads. High temperature jets of flame are directed against the tunnel

face, and as the cutting head rotates the flame-jets cut into the rock. Other attachments on the cutting head break off the rock and dump it onto a muck conveyor to be carried to the back of the machine (See Illustrations 34 and 35). There the muck is transferred to the cars of a muck train to be carried to the rear of the tunnel, and hoisted to the service for disposal.

Due to the combustion gases and high temperatures generated by the flames the tunneling crew would ride behind the tunneler in a climate controlled cab (See Illustration 36). When they ventured outside, into the tunnel environment, they would wear suits like those that astronauts wear, to protect them from the heat and poisonous gases in the tunnel (See Illustration 37). The actual size of the tunnel could be as much as 30 ft. in diameter. Power would be drawn from a high-voltage electrical supply.

Flame-jet tunneling would leave a smooth wall, as the flame seared and broke the rock. Vol. I of the report estimates the cost of flame-jet tunneling for a 20 ft. diameter tunnel, at anywhere from 44% to 28% of the cost of the drill and blast method. The authors of the report state that flame-jet tunneling is especially suited for very hard rock tunneling, where mechanical TBMs have a much slower rate of progress.[7]

The second volume of the report runs to more than 350 highly detailed pages of cost and efficiency analysis, engineering studies, and various other plans for using flame-jet tunnel machines to construct a tunnel system 1,000 ft. underground.[8] The third volume discusses dated, conventional tunneling techniques.

As with so much else in this report, the flame-jet tunneling documents are real. But have actual flame-jet tunneling machines been built? And are there really flame-

jet tunneling crews in "moon suits" 1,000 ft. underground, boring through the bedrock, making secret tunnels for who-knows-what reason?

Pulsed Electron Tunnel Excavator

This exotic piece of equipment turned up in a single article.[9] Like the other nonconventional tunneling machines, it is presented as an interesting, but untried technology. The article speaks of a Pulsed Electron Tunnel Excavator that would in theory be "capable of tunneling approximately ten times faster than conventional drill/blast methods." It would do this by wearing away the rock face with a very high voltage beam of electrons, something like an electronic sand blaster. Most of the resulting muck would be small particles of sand and dust that would flake off and be removed from the tunnel face by a slurry pipeline. Larger chunks of rock would be removed by a conveyor (See Illustration 38).

Has this machine really been built, or is it just another Buck Rogers scheme that never got past the conceptual design stage? I don't know — but if you do, contact me with the relevant details.

Nuclear Subterrenes

The nuclear subterrene (rhymes with submarine) was designed at Los Alamos National Laboratory, in New Mexico. A number of patents were filed by scientists at Los Alamos, a few federal technical documents were written - and then the whole thing just sort of faded away.

Or did it?

Nuclear subterrenes work by melting their way through the rock and soil, actually vitrifying it as they go, and leaving a neat, solidly glass-lined tunnel behind them.

The heat is supplied by a compact nuclear reactor that circulates liquid lithium from the reactor core to the tunnel face, where it melts the rock. In the process of melting the rock the lithium loses some of its heat. It is then circulated back along the exterior of the tunneling machine to help cool the vitrified rock as the tunneling machine forces its way forward. The cooled lithium then circulates back to the reactor where the whole cycle starts over. In this way the nuclear subterrene slices through the rock like a nuclear powered, 2,000 degree Fahrenheit earthworm, boring its way deep underground.

The United States Atomic Energy Commission and the United States Energy Research and Development Administration took out patents in the 1970s for nuclear subterrenes. The first patent, in 1972 (See Illustration 39) went to the U.S. Atomic Energy Commisssion.

The nuclear subterrene has an advantage over mechanical TBMs in that it produces no muck that must be disposed of by conveyors, trains, trucks, etc. This greatly simplifies tunneling. If nuclear subterrenes actually exist (and I do not know if they do) their presence, and the tunnels they make, could be very hard to detect, for the simple reason that there would not be the tell-tale muck piles or tailings dumps that are associated with conventional tunneling activities.

The 1972 patent makes this clear. It states:

...(D)ebris may be disposed of as melted rock both as a lining for the hole and as a dispersal in cracks produced in the surrounding rock (italics mine). The rock-melting drill is of a shape and is propelled under sufficient pressure to produce and extend cracks in solid rock radially around the bore by means of hydrostatic pressure developed in the molten rock ahead of the advancing rock drill penetrator. All melt not

used in glass-lining the bore is forced into the cracks where it freezes and remains ...

... Such a (vitreous) lining eliminates, in most cases, the expensive and cumbersome problem of debris elimination and at the same time achieves the advantage of a casing type of bore hole liner.[10]

There you have it: a tunneling machine that creates no muck, and leaves a smooth, vitreous (glassy) tunnel lining behind.

Another patent three years later (See Illustrations 40 and 41) was for:

A tunneling machine for producing large tunnels in soft rock or wet, clayey, unconsolidated or bouldery earth by simultaneously detaching the tunnel core by thermal melting a boundary kerf into the tunnel face and forming a supporting excavation wall liner by deflecting the molten materials against the excavation walls to provide, when solidified, a continuous wall supporting liner, and detaching the tunnel face circumscribed by the kerf with powered mechanical earth detachment means and in which the heat required for melting the kerf and liner material is provided by a compact nuclear reactor.[11]

This 1975 patent further specifies that the machine is intended to excavate tunnels up to 12 meters in diameter or more. This means tunnels of 40 ft. or more in diameter. The kerf is the outside boundary of the tunnel wall that a boring machine gouges out as it bores through the ground or rock. So, in ordinary English, this machine will melt a circular boundary into the tunnel face. The melted rock will be forced to the outside of the tunnel by the tunnel machine, where it will form a hard, glassy tunnel lining

(see the appropriate detail in the patent itself, as shown in Illustration 41). At the same time, mechanical tunnel boring equipment will grind up the rock and soil detached by the melted kerf and pass it to the rear of the machine for disposal by conveyor, slurry pipeline, etc. (See Illustrations.)

And yet a third patent was issued to the United States Energy Research and Development Administration just 21 days later, on 27 May 1975 for a machine remarkably similar to the machine patented on 6 May 1975. The abstract describes:

A tunneling machine for producing large tunnels in rock by progressive detachment of the tunnel core by thermal melting a boundary kerf into the tunnel face and simultaneously forming an initial tunnel wall support by deflecting the molten materials against the tunnel walls to provide, when solidified, a continuous liner; and fragmenting the tunnel core circumscribed by the kerf by thermal stress fracturing and in which the heat required for such operations is supplied by a compact nuclear reactor.[12]

This machine also would be capable of making a glass-lined tunnel of 40 ft. in diameter or more.

Perhaps some of my readers have heard the same rumors that I have heard swirling in the UFO literature and on the UFO grapevine: stories of deep, secret, glass-walled tunnels excavated by laser powered tunneling machines. I do not know if these stories are true. If they are, however, it may be that the glass-walled tunnels are made by the nuclear subterrenes described in these patents. The careful reader will note that all of these patents were obtained by agencies of the United States government. Furthermore, all but one of the inventors are from Los Alamos, New Mexico.

Of course, Los Alamos National Lab is itself the subject of considerable rumors about underground tunnels and chambers, Little Greys or "EBEs", and various other covert goings-on.

A 1973 Los Alamos study entitled Systems and Cost Analysis for a Nuclear Subterrene Tunneling Machine: A Preliminary Study, concluded that nuclear subterrene tunneling machines (NSTMs) would be very cost effective, compared to conventional TBMs. It stated:

Tunneling costs for NSTMs are very close to those for TBMs, if operating conditions for TBMs are favorable. However, for variable formations and unfavorable conditions such as soft, wet, bouldery ground or very hard rock, the NSTMs are far more effective. Estimates of cost and percentage use of NSTMs to satisfy U.S. transportation tunnel demands indicate a potential cost savings of 850 million dollars (1969 dollars) through 1990. An estimated NSTM prototype demonstration program cost of $100 million over an eight-year period results in a favorable benefit-to-cost ratio of 8.5.[13]

Turn to Illustration 42, which is reproduced from a second 1973 Los Alamos study, this one entitled Large Subterrene Rock-Melting Tunnel Excavation Systems: A Preliminary Study and compare it to Illustration 41, from the patent issued in 1975. Without belaboring the point, I would like to call attention to the almost exact duplication of shared elements in these two drawings. Was the 1973 feasibility study only idle speculation, and is the astonishingly similar patent two years later only a wild coincidence? As many a frustrated inventor will tell you, the U.S. Patent Office only issues the paperwork when it's satisfied that the thing in question actually works!

In 1975 the National Science Foundation commissioned another cost analysis of the nuclear subterrene. The A.A. Mathews Construction and Engineering Company of Rockville, Maryland produced a comprehensive report with two, separate, lengthy appendices, one 235 and the other 328 pages.

A.A. Mathews calculated costs for constructing three different sized tunnels in the Southern California area in 1974. The three tunnel diameters were: a) 3.05 meters (10 ft.); b) 4.73 meters (15.5 ft.); and c) 6.25 meters (20.5 ft.). Comparing the cost of using NSTMs to the cost of mechanical TBMs, A.A. Mathews determined:

Savings of 12 percent for the 4.73 meter (15.5 ft.) tunnel and 6 percent for the 6.25 meter (20.5 foot) tunnel were found to be possible using the NSTM as compared to current methods. A penalty of 30 percent was found for the 3.05 meter (10 foot) tunnel using the NSTM. The cost advantage for the NSTM results from the combination of (a) a capital rather than labor intensive system, and (b) formation of both initial support and final lining in conjunction with the excavation process.[14]

This report has a number of interesting features. It is noteworthy in the first place that the government commissioned such a lengthy and detailed analysis of the cost of operating nuclear subterrenes. Just as intriguing is the fact that the study found that tunnels in the 15 ft. to 20 ft. diameter range can be more economically excavated by NSTMs than by conventional TBMs.

Finally, the southern California location that was chosen for tunneling cost analysis is thought provoking. This is precisely one of the regions of the West where there is rumored to be a secret tunnel system. Did the A.A.

Mathews study represent part of the planning for an actual, covert tunneling project that was subsequently carried out, when it was determined that it was more cost effective to use NSTMs than mechanical TBMs?

Whether or not nuclear subterrene tunneling machines have been used, or are being used, for subterranean tunneling is a question I cannot presently answer. If you should happen to know, contact me with the relevant proof.

Nuclear Subselene Tunneling Machines On The Moon?

No discussion of government plans for secret tunneling projects would be complete without considering NASA's plans for tunneling on the Moon.

1980s documents from Los Alamos National Laboratory and from Texas A&M University (under contract to NASA) indicate that there are plans to use "nuclear subselene tunneling machines" to melt tunnels under the Moon's surface, to make living, working, mining and transportation facilities for a lunar colony.

A 1986 Los Alamos report[15] calls for using a fission powered, nuclear subselene to provide the heat to "melt rock and form a self-supporting, glass-lined tunnel suitable for Maglev or other high-speed transport modes." The report recommends burrowing beneath the surface because of the harsh lunar environment. It further mentions that the tunnels would "need to be hundreds, or thousands of kilometers long ..." The actual subselenes would be automatic devices, remotely operated. In 1986, Los Alamos estimated each subselene could be built for about $50 million and transported to the Moon for anywhere from $155 million to $2,323 million. The price tag may seem exorbitantly high, but rest assured that there is easily that

much, and more, available in the military's "black" budget for covert projects. It should be noted that the report did not specify how the nuclear subselenes and their crews would be transported to the Moon.

A 1988 Texas A&M study outlined plans for a slightly different model of lunar tunnel boring machine. The Texas A&M "Lunar Tunneler" would employ a "mechanical head to shear its way through the lunar material while creating a rigid ceramic-like lining" (See Illustration 43). Essentially, this kind of machine would be a hybrid, mechanical TBM that incorporates elements of the nuclear powered subselene. Although the machine would be nuclear powered it would have a mechanical cutter head that would bore through the lunar subsurface. Just behind the cutter head would be a "heating section" that would "melt a layer of lunar material within the excavated tunnel to a depth of only a few inches. This molten material could then be cooled to form a rigid ceramic material suitable for lining the interior of the tunnel."[16]

The Texas A&M designers considered a couple of different muck disposal schemes. The two variants of the first called for the muck to be transferred vertically to the surface and either dumped or "sprayed" into a tailings pile (See Illustration 44). The second concept called for the use of special, tunnel dump trucks that would carry the muck out of the tunnel and dump it on the lunar surface (See Illustration 44). The designers recommend use of an SP-100 fission reactor for power, using liquid lithium heat pipes of the sort developed by Los Alamos National Laboratory for the nuclear subterrene.[17]

A second Texas A&M study, released in May 1988, also recommended use of a lithium cooled nuclear reactor as the power source for a lunar tunneler. In the second tunneler design, there are no mechanical tunneling

components. Instead, the cone-shaped, nuclear powered tunneler melts its way through the subsurface like a subterrene. Some of the melted rock and soil is plastered against the tunnel walls to form a glass-like ceramic tunnel lining. The rest of the melted muck (called regolith) is passed out of the back of the tunneler and then carried to the surface for disposal by the dump trucks that follow the tunneler through the tunnel.[18]

I don't know if there are nuclear tunneling machines secretly making permanent bases and tunnels on the moon. But the NASA plans certainly give cause to wonder.

Chapter Seven

NUCLEAR TESTING, THE EPA, ABDUCTIONS, ANIMAL MUTILATIONS (AND ALIENS?)

If you think the federal government's involvement in secret underground bases is thought-provoking, consider the evidence presented in this chapter of similarities between some aspects of UFO-type "abductions" and the activities of a couple of well-known government agencies.

The tenure of Hazel O'Leary as Secretary of the Department of Energy (DOE) has breathed fresh life into DOE's public relations strategy. O'Leary's commitment to the release of information on nuclear testing in decades past has triggered a slew of unsettling news reports of numerous government-sponsored radiation experiments performed on American citizens in the post-WW II period.

In some cases, it appears the subjects gave their informed consent. In others, it is clear that the subjects had no idea that they were being exposed to radioactive substances, or to radioactive fallout. For example, in one case, people were given plutonium injections without their knowledge or consent. In another case, citizens of northern New Mexico were exposed to radioactive clouds that wafted over the region subsequent to the vaporization of radioactive elements at Los Alamos National Labs by conventional explosives.

New information continues to be made public about the extent to which widely divergent sectors of the public have been exposed to the radioactive poisons released by the military, the former Atomic Energy Commission and its successor, the Department of Energy. Given what has been

revealed so far, the scope of the public's exposure to potentially harmful radiation sources could be far greater than the federal government has led us to believe.

In fact, the existence of a little-known human surveillance and monitoring program run by the Environmental Protection Agency (EPA) suggests that it may well be. Interestingly, in conjunction with the human surveillance and monitoring program the EPA also conducts a milk sampling and animal monitoring program. All of these programs are designed to detect the presence of abnormal levels of radioactive isotopes in the body tissues of the human and animal subjects they monitor.

What does any of this have to do with the so-called "abductions" and "animal mutilations" that have been prevalent in the UFO literature in recent years? As it turns out, there is an uncomfortably close parallel or similarity between the EPA's activities and some of the strange goings-on that many UFOlogists have attributed to supposed aliens, such as the infamous "Little Greys".

To begin with, there is a coincidence in time. The government testing program is run by the EPA, which was established in 1970. As it happens, the human abduction and animal mutilation reports began to occur in large numbers over the last 20 years. During that period there has been a virtual deluge of reports in the UFO literature concerning purported abductions of unwilling humans by aliens. In many cases, those who have alleged themselves to have been abducted report that they were subjected to a variety of procedures that resemble, however darkly, some sort of medical examination. There are many reports of sperm and ova samples being taken. Various cuts, scars and scoop marks are said to be the result of alien probing of human bodies. And in many cases, people report being laid on some sort of examining table and having their bodies scanned with some sort of high-tech instrument that is used to examine them from head to toe, in somewhat the same manner that Magnetic Resonance Imagers (MRIs) are

used today.

And there have been many reports of mutilations of animals. As with human abductions, these mutilations are also alleged to be the work of intrusive aliens. For the most part, the alleged mutilations have occurred with farm animals such as cattle and horses. Various body parts are reportedly taken, such as cow udders, anuses, sex organs, tongues, lips and the occasional internal organ. In addition, these mutilations are frequently said to involve the draining of the animal's blood.

First reported in large numbers in the 1970s, mysterious animal mutilations are alleged to continue to the present day, with cases reported recently in Colorado, New Mexico and Alabama.

In broad outline, these are the facts as alleged by numerous personalities in the UFO field. I do not claim to be an expert in these matters or to know whether or not alien abduction and examination of humans and alien mutilation of animals are, or are not, occurring. I am willing to give a hearing to those who maintain that they are occurring. But I am not able personally either to rigorously prove or disprove the sensational claims that many have made in recent years. I have taken the attitude of a juror in a complex, confusing legal proceeding. I am biding my time, waiting for more and better evidence before deciding one way or the other with respect to these matters.

A real U.S. government surveillance program

Having said that, there is solid documentation for an ongoing, years-long U.S. government program of human surveillance, involving medical examinations and scanning of the entire body. There is equally strong documentation for an ongoing, years-long program in which animals, including horses and cattle, are killed and body parts and tissues, including the blood, are collected and analyzed. This program, detailed in a 1989 government report, is

carried out by the EPA. It is the official United States government offsite monitoring project for detection of radioactive contamination from nuclear testing at the Department of Energy's Nevada Test Site.

As part of the program, 31 air monitoring stations are set up throughout the southern two-thirds of the state of Nevada, in western Utah, and in California near the border with Nevada. Air samples are collected three times a week. Air samples are also collected every three months and analyzed for radiation at 86 other air monitoring stations scattered throughout the states west of the Mississippi. Some 130 other locations throughout Nevada, Utah, northwestern Arizona and parts of California near the Nevada border are monitored with thermolumiscent dosimeters designed to record levels of absorbed radiation. These stations are checked every three months as well. Additionally, the water in 51 wells both on and off the test site is checked monthly for radioactive contamination.

Most interesting for UFOlogists, there is an ongoing human surveillance program in which about 40 families are closely monitored. These people live near the test site and are brought in by the Environmental Protection Agency twice a year to be scanned by a "whole body counter" (See Illustration 45). Notice the small room and padded, reclining chair on which persons being examined lie. Notice, too, the whole body counter which telescopes down from the ceiling to examine the subject. Oddly enough, the small room, the reclining chair and the examination instrument are very strongly reminiscent of the small chambers, examining tables and body scanners alleged to be used during purported alien abductions. The fact that families are examined is also interesting, in that the (supposed) alien abduction scenario also seems to sometimes involve abduction and examination of more than one individual in a family.

A variety of animals are also periodically examined. These include cattle purchased from herds near the test

site, as well as bighorn sheep, mule deer, chukar and horses that are shot by hunters or killed in accidents. The tissues and organs are then analyzed for radioactivity. These include muscle, lung, liver, kidney, bone and blood (yes, blood is a tissue). Here again, there is a clear parallel strongly reminiscent of alleged animal mutilations by aliens, involving some of the same species, as well as some of the same tissues.

Finally, there is a milk sampling program. Every month the EPA analyzes raw milk from about 25 farms in Nevada and adjacent areas of Utah and California (See Illustration 46). Raw milk from 120 other farms in states west of the Mississippi is analyzed on an annual basis (See Illustration 47). This is done because grazing cows ingest radioactive particles that may be deposited on their pastures by air or rain. These particles then pass through their udders and into their milk. So analyzing cows' milk is a convenient way of detecting radioactive contamination of the environment.

Here again, there may be a parallel with alleged alien animal mutilations, although in this case the connection (if it exists) may be more indirect. In many so-called cattle mutilations, the udder of the victimized animal is conspicuously cut out and removed. Of course, the udder contains the milk producing glands of the cow. Consequently, anything present in a cow's milk would logically pass through and/or be present in its udder as well.

Presumably, then, analyzing udder tissues would reveal many of the same radioactive substances, if present, that an analysis of milk produced by those same udders would reveal. As it happens, milking a cow takes time. This might present a problem for busy aliens operating under rigid time constraints (assuming aliens are responsible for the mutilations). Might it be conceivable that under the circumstances it is simpler for "them" just to cut and run?

Who is behind the mutilations and "abductions"?

Whatever the truth of the matter, it is curious that the U.S. government has a testing program that monitors both animals and humans in ways that so strongly mimic the pattern of activity characteristic of alleged alien abduction of humans and alleged alien mutilation of animals, particularly cattle. Is there a connection between the official, albeit little known, government program and the numerous abduction and mutilation stories that have swirled through the UFO world? If so, what is the nature of the link? Are the alleged alien abductions and mutilations really part of a much wider, more pervasive program of covert monitoring of humans and animals by the government? Are alleged aliens and UFOs a convenient cover story that secret government agencies use to hide their tracks? Are the alleged abductors and mutilators really terrestrial humans, working undercover for the U.S. government or some other, non-governmental, covert agency? And if they are, what is the purpose of such an extensive monitoring program? One shudders to think. From the standpoint of violated civil liberties alone the implications would be sobering. And it may mean that the nuclear genie has let loose something unspeakably horrendous from its atomic bottle, the awful nature of which has yet to be divulged to us.

Or are real, live aliens to blame for the reported abductions and mutilations? Is it mere coincidence that their activities so closely resemble those of the U.S. government? Or are they running a testing program that is basically looking for the same things as the EPA? Do they share the same concerns? Are they operating independently of one another? Or are aliens and covert elements of the U.S. government perhaps working together? And if so, for what reason? Of course, this line of speculation assumes that there are aliens in the first place, and that if there are, that they are involved in abducting and examining humans and also in killing and mutilating

animals.

Whatever the case may be, we are left with the reality of the reports of "alien abductions", as well as carcasses of animals allegedly killed and mutilated by aliens. The precise reality behind the reports of abductions and the precise circumstances surrounding the deaths and mutilations of the animals are not known for certain. We must remember that not much is known about these incidents.

Debunkers have chalked up the dead animals and mutilations to normal disease, accidents and predator activity. Likewise, they decry the tales of abductees as dreams, flights of fancy and fevered imaginings. And maybe the debunkers are right.

On the other hand, the mounting weight of anecdotal evidence from numerous witnesses who attribute these incidents to alien activity cannot easily be ignored. It does seem possible that something highly strange, perhaps involving another sort of intelligent, and certainly very exotic, species is going on. But in the final analysis, it is virtually impossible to say for sure.

What can be said for certain is that in recent years the U.S. government has had an extensive human and animal surveillance and monitoring program which in several essential aspects closely resembles activities often attributed to supposedly alien beings.

Curious to know more about possible EPA activities in this regard, in late January 1994 I called the agency's office in Las Vegas, Nevada to find out the official government line on animal monitoring and human surveillance. After being passed around in the bureaucracy for a couple of hours I eventually received a call from a noticeably wary spokeswoman who doled out information to me by dribs and drabs. She sighed; she hemmed and hawed; she pled ignorance; she referred me to another office; she equivocated; she spoke indistinctly; she paused and hesitated in her answers.

But at my persistent urging she did admit the following: human surveillance around the Nevada Test Site began around 1957, and today includes about 100 people, many of them from local ranching families, both parents and children. These people are brought in to the Environmental Systems Monitoring Laboratory at the University of Nevada-Las Vegas, where their bodies are scanned for radioactive isotopes by a "whole-body counter". She said that some of these people have been continuously tracked since the late 1960s. The spokeswoman said she did not know if similar programs of human surveillance are conducted near the nation's other nuclear laboratories and test facilities, such as Savannah River, South Carolina; Hanford, Washington; Pantex, Texas; Sandia and Los Alamos, New Mexico; and Oak Ridge, Tennessee.

Where animals are concerned, sampling began in Nevada before 1960. I was told the program consists of a man who is sent out in a truck and told the number and kind of animals to slaughter for testing. The spokeswoman said that there is no animal monitoring outside of Nevada. However, in response to my prodding she did say that Lovelace Medical Center, in Albuquerque, New Mexico, may have done some animal monitoring as a follow-up to dispersion of radioactive isotopes from nuclear testing at Los Alamos National Laboratories, in northern New Mexico. But she was not certain of this, and mentioned it only as a possibility.

But whether true or not, it is an intriguing thought. Lovelace has had a long relationship with the military-industrial complex that continues to the present day. And Lovelace currently operates a large, sophisticated, animal research facility on the grounds of the Sandia National Laboratories/Kirtland Air Force Base complex on the outskirts of Albuquerque (as well as medical facilities for humans, also in the Albuquerque area). Of course, this in no way proves that Lovelace is involved in animal mutilations (or human abductions). On the other hand,

Albuquerque is awfully close to the areas of northern New Mexico and southern Colorado where so many cattle mutilations have been reported. And if the mutilations and abductions are being done by covert human operators, since the medical expertise at Lovelace and the helicopters and other equipment from Kirtland AFB and Sandia National Laboratories are as state-of-the-art as can be found anywhere, one could speculate there might be a connection.

On a final note, since unmarked, dark helicopters are sometimes reported in the vicinity of animal mutilations, I asked the EPA spokeswoman whether the EPA ever used helicopters to carry out its animal testing program. She denied that the EPA operates in this way.

And that was the end of the interview. As I hung up the phone I was struck by the spokeswoman's reticence to divulge information. I had the distinct feeling she could have told me a great deal more than she did.

In the end, the same question remains: what is going on? We have numerous reports of human abductions, and medical-like testing by seemingly alien beings. There are also many reports of animal mutilations, under strange circumstances, with conspicuous removal of selected body parts. During the same period of time, there is solid evidence from the EPA of an ongoing nuclear contamination monitoring program involving prolonged human surveillance and animal testing that resembles, to a surprising degree, activities often attributed to aliens.

These are the facts as they have been presented by the government and by concerned individuals who allege to have seen and/or experienced animal mutilations and human abductions. To say more than that is to take liberties with the truth. The best I can do is to observe that past this point things become very murky indeed.

Chapter Eight

ABDUCTIONS, NEEDLES AND IMPLANTS: A FRESH APPROACH

The UFO literature is rife with reports where alleged aliens insert small implants into the bodies of abductees. On occasion the implants are said to be put in place with needle-like devices. Locations of particular choice seem to be behind the ear, and up the nose, in the top of the nasal cavity. The reasons for these abductions, as well as the nature of the implants themselves, remain perfectly obscure. To begin with, it is not clear who is perpetrating the abductions; and neither is it clear what function(s) the implants perform.

But given the constantly growing number of people who are reporting these sorts of incidents it seems to me that UFOlogists ought to look more closely at this aspect of the UFO phenomenon. The most simple questions about the abductors and implants beg to be asked: Who? How? Why?

Many abductees, perhaps most, identify their abductors as "aliens". The assumption is often made, and sometimes forthrightly, that these "alien" abductors are extraterrestrial beings. Of course, this assumption may or may not be true. In fact, it may be the case that at least some of the "alien" abductors are actually terrestrial humans working covertly, under cover of artificially induced states of total or partial amnesia, fear and screen memories. There are a wide variety of techniques that can influence, even deeply alter, human perception and emotions. These can be as simple as the use of rubber

masks and make-up (how about a reptilian face mask and body suit?). More sophisticated technologies can cause profoundly realistic hallucinations. Psycho-active drugs, certain microwave radiations, various hypnotic procedures, and flashing lights and rhythmic sounds are some of the ways in which this can be done.

To be sure, there are many, many reports of abductees being asked to drink strange potions and decoctions; smelling strange vapors and gases; seeing flashing lights; gazing deeply into hypnotic eyes; experiencing strange radiations; hearing whirring or humming sounds; and hearing voices in their heads.

I think we have to at least consider the possibility that some of these reported aspects of abductions may actually be earthly technologies used by terrestrial humans to radically alter a subject's perception of reality during an "alien abduction" experience.

There are any number of groups, governmental or private, that have, or could obtain, access to the money, personnel, equipment, materials and expertise to stage a convincing "alien abduction" episode. These organizations include (but are not by any means limited to): the police, intelligence and military agencies of major governments; major corporations and powerful financial institutions operating on a global scale; transnational organizations such as the United Nations, NATO, Tri-Lateral Trade Commission, and Inter-Pol; and other secretive, international organizations such as crime syndicates and fraternal orders.

Consider that some "alien abductees" do, in fact, report seeing other human beings during their abductions, human beings who appear to be involved in, or cooperating with the perpetrators of, the abduction. In some cases these other humans have reportedly been in military uniform. These curious reports certainly suggest the possibility of at least some degree of covert involvement by terrestrial humans in the "alien abduction"

phenomenon.

Of course, just because "alien abductees" allege that "aliens" or "extraterrestrials" used needles or syringe-like devices to insert implants into their bodies, does not necessarily mean that aliens or extraterrestrials of any sort actually did it. It only means that "alien abductees" say that is what has happened. The report may be ever so heartfelt - and many of the accounts are extremely moving and sincere -- but at one and the same time, the report may, or may not, accurately reflect what actually transpired.

Alternate Realities of the Terrestrial Kind

Here are some hard facts: there is now a technology in commercial use that almost precisely mirrors the needle-injected implants said to be inserted into abductees by aliens. There are several companies that now offer miniature, electronic, identification devices for sale, primarily for use in animal-related applications, so that farmers, ranchers and pet owners can keep track of their herds, flocks and pets.[1]

As will be made clear below, these electronic tracking devices are perfectly capable of being injected into humans, as well.

One United States firm, a leader in the field of electronic implants, holds a number of related patents. It manufactures miniature, electronic implants that are injected using a large syringe and needle.

Please note that I am not saying that this U.S. firm, or any other firm making similar products, is in any way involved with the alleged "alien abduction and implantation" phenomenon. But products are being marketed in the United States that are remarkably similar to the implant technology frequently reported in the "alien abductee" literature.

In recent years a series of U.S. Patents have been awarded for an electronic identification system based on

syringe-implantable identification transponders (implants).[2] According to the patents the system involves inserting tiny implants "into animals for their identification, useful in monitoring migratory patterns and for other purposes." The implants are "durable and reliable over a period of years." Moreover, each of the implants are uniquely identifiable.

These "injectable transponders" are about four-tenths of an inch long and less than one-tenth of an inch in diameter.[3] They contain electronic micro-circuits that are activated and read by "a compatible radio-frequency ID reading system." The tiny, "bio-compatible glass" implants contain "an electromagnetic coil, tuning capacitor, and microchip." According to product literature from one of the U.S. makers of these injectable transponders, the chips can be programmed with up to "34 billion unique, unalterable identification codes." The literature says that although the injectable transponders are "specifically designed for injecting in animals, (they) can be used for other applications requiring a micro-sized identification tag."

The transponders are injected with a syringe-like device with a needle on the end. According to the relevant patent the injector needle is "adjustable for implant insertion depth." The patent states that "needles ... of various diameters and lengths may be interchanged in the injector." It specifies that where needle dimensions are concerned "the invention may be adapted to a large range of dimensions." Furthermore, it says the "needle may also be rotated to a plurality of positions relative to the injector handle."[4]

In other words, the device described in this patent could be fitted with a needle that would permit an implant in a variety of locations in the human body, including many, if not all, of the locations reported by people who believe they have been subjected to an "alien abduction and implantation".

Interestingly, three of the patents granted for identi-

fication devices (transponders/implants) explicitly state, in identical language, that the devices are to be "carried by or embedded in the thing or animal to be identified." All three also explicitly state: "the primary object of this invention is to provide a system for identifying an object, animal or person..."[5] (my italics) (See Illustration 48).

Furthermore, when the implant is "read" at the appropriate radio frequency the output can be displayed on a computer terminal and transferred to an electronic data storage system.[6]

In plain language, what we have here is the type of technology that, if employed on a large scale, could theoretically electronically monitor, in real time, the whereabouts and movements of as many as 34 billion individual animals or humans. Of course, the possibilities and implications for potential political and social control are both obvious and enormous.

I would like to stress again that my research has not shown that any manufacturers or buyers of these injectable transponders are, in any way, either directly or indirectly, involved in either the so-called "alien abduction and implantation" phenomenon, or in monitoring the whereabouts and movements of human beings. I am only using these products as examples of the kind of off-the-shelf implantation and monitoring technology that is being manufactured and marketed today.

What's behind the "abduction" phenomenon?

If social or political control is the motive behind the abductions and implants (and I do not know that it is), then how would such control be carried out? One possible answer is: genetically.

Abductees frequently report that their abductors seem preoccupied with human sexuality and breeding. The abductee literature is full of reports of forced breeding; collection of human ova and sperm from unwilling

abductees; stolen fetuses from pregnant abductees; and allegations of a human/alien crossbreeding or hybridization project.

To be sure, the accounts of "alien abuctions", taken all together, make for a bizarre collection of literature. But suppose the stories contain an element of truth - at least in broad outline?

Let us assume, hypothetically, that there is some kind of covert human breeding program going on, for reasons known only to the abductors (whoever they might be). Those reasons need not necessarily be those given by the abductors, or inferred by the abductees.[7] For the sake of example, suppose the abductors for whatever reason want to mate a 40 year old woman in Des Moines with a 22 year old man in Bombay; or a 34 year old woman in London with a 65 year old man in Tokyo? Of course, these are people living in different countries, speaking different languages, immersed in different cultures and religions. The chances that they would pair up and mate if left to their own devices are minuscule.[8]

Enter our mystery abductors, to do their covert, "alien" match-making. Abductees might be physically mated (as is sometimes reported in the literature). Or, where this is not feasible, sperm and ova samples collected from unwilling donors could be stored, then mixed and matched later for the desired genetic combination. Fertilized eggs could be implanted; fetuses could be removed. In vitro fertilization and artificial wombs could be used to produce fetuses and bring them to term.[9]

Clearly, if any known organization openly went around in this way, forcing people to mate with one another against their will, the hue and cry would be enormous. Society would be in an uproar. So any large scale, forced-breeding program would have to be very secret to be successful. And the perpetrators would certainly have to carefully conceal both their identities and motives in order to avoid being caught out by their victims

and the public at large. Obviously, they would have to be very stealthy in picking up and monitoring their "breeders."

The fact that human reproductive capacities change also complicates matters. People reach puberty; they get pregnant; they reach menopause; they have their tubes tied; they have vasectomies; their ova/sperm become fertile/infertile. How to tell whether the person(s) of interest can produce viable offspring? And how, finally, to find the desired persons on any given day, at any given hour?

Enter the electronic monitoring and identification implant. Product literature from at least one U.S. manufacturer discusses how an animal breeder (farmer) can use their product to identify and monitor the breeding status of hogs and cows. The question naturally arises as to whether the same (or very similar) technology is being used by others who regard abductees as part of their "herd."[10] Are abductees perhaps implanted for the same reasons that a hog farmer monitors his pigs -- to keep track of their breeding status?

It is an interesting line of speculation which may or may not be related to the "implant" aspect of the abduction phenomenon of recent years. And it may or may not have anything to do with purported "alien" activities on this planet. But I think the reader will agree that the very real implant technology discussed earlier in this chapter bears more than a little resemblance to the implant technology often attributed to alleged "alien" abductors.

Might we be dealing with a covert implantation/ monitoring program that is being carried out very stealthily and furtively by very real human agencies and operatives? Might they have a devious motive of political and social - or even physical -- control? Are they carrying out a massive, secret, forced-breeding program? Might they use the UFO and "alien" abduction phenomenon as a convenient screen, a sort of otherworldly camouflage to conceal their true identity and purpose?

This whole affair is wonderfully bewildering. On the one hand, there does seem to be a genuine abduction phenomenon, with growing numbers of people who reportedly have been implanted by perpetrators who have so far proven to be impressively elusive and stealthy. They have also proven extraordinarily adept at passing themselves off as "aliens" or "extraterrestrials".

On the other hand there is now a commercially available, human manufactured, terrestrial technology that closely resembles the implant technology that has repeatedly been reported to be used by "aliens." It is true that the patents for this technology are of comparatively recent vintage; however the technology itself could well have been developed long before the patents were issued. After all, electronic micro-ciruits have been around for years now. In any event, the fact that the two technologies are so extraordinarily similar raises the question as to whether they might not actually be the same. And if they are the same, then we have to begin looking for a very human, home-grown connection to at least some of the reported abductions.

In the end we find ourselves stuck in a bizarre hall of mirrors full of constantly shifting, bizarre images, each one more improbable than the next. Are the images alien? Human? Are the perpetrators hiding behind disinformation or propaganda masks? Hypnotic masks? Electronically or chemically induced masks?[11]

To be sure, there may be even more troubling permutations of the abduction and implantation phenomena.

For example, entertain the following possibilities: Group "A" (the Army, CIA, NSA, "aliens") abducts and implants human subject "X". Meanwhile, Group "B" (select your favorite from the rogue's gallery above) either strongly suspects or somehow knows that subject "X" has been abducted and/or implanted. However, "B" is not sure how, why or when subject "X" was abducted and

implanted.

But "B" would very much like to know who has abducted and/or implanted "X" - as well as when and why. So "B" also abducts and implants subject "X." In this way, "B" can keep close electronic tabs on "X" and if "A" again abducts subject "X", "B" will be able to monitor the abduction. "B" may even be able to establish when it occurs and the location to which "X" is taken.

Group "B" may even be able to monitor the abduction in progress, thereby discovering the identity of Group "A."

Obviously, this game would be a strange one. Kick back and let your imagination run with the possibilities. What if Group "A," for instance, is the U.S. Army and "B" is the U.S. Air Force?

Now, try a variation on the theme. Let "A" be a joint U.S. Army-"alien" alliance, and let "B" be the U.S. Air Force. Liven things up by adding another "alien" group, and another military agency. Suppose that international organizations like the United Nations are also involved, perhaps with interests that are in direct conflict with those of Group "A" or Group "B" -- or perhaps most importantly, with those of human subject "X".

The point I am making is simply that the abduction and implantation phenomena may have interlocking layers of complexity that have not been sufficiently explored or appreciated by most UFO researchers.

Oh, yes. One final thing.

If the possibility of being implanted and electronically tracked and monitored (perhaps without your knowledge or consent) makes you feel a trifle uneasy, just try repeating the following words softly to yourself until you feel more relaxed: "New World Order ... New World Order ...New World Order..."

Chapter Nine

IS THE U.S. MILITARY INVOLVED IN "ALIEN" CATTLE MUTILATIONS?

For years investigators of the cattle mutilation phenomenon have reported that wounds and cuts on many of the mutilated carcasses seem to have been made by some sort of surgical laser device. The unnatural precision and cleanliness of incisions, as well as evidence of unnatural heating of the tissues near the wounds have all pointed to probable use of surgical laser scalpels in many cattle mutilations.

Though there is little doubt that the mutilations are occurring, it has not been clear who the mutilators are. There have been many allegations that the mutilators are "aliens" or extraterrestrials - but no hard proof.

For many years, the working assumption has been that human involvement in the mutilations was not possible because there is presumed to be no known "earthly" technology that could carry out these mysterious mutilations. Reasons given include such factors as the surgically precise, "laser-like" incisions and wounds (allegedly impossible with contemporary medical technology); lack of footprints; and absence of blood around mutilated carcasses.

But the presence of mysterious, unidentified helicopters in the vicinity of many cattle mutilations has long been noted. The fact that helicopters are a 20th century, terrestrial technology has led to speculation that

the "alien" hypothesis for the cattle mutilations may not satisfactorily explain every facet of the phenomenon.

In fact, there may be very real, covert human involvement in the cattle mutilations. To begin with, it is simply not true that modern medical technology cannot and has not produced a portable, surgical laser that can be taken into the field (literally!).

The Phillips Laboratory at Kirtland Air Force Base, in Albuquerque, New Mexico recently announced that it has developed a "very compact device" called the "Laser Medical Pac" that provides the "field paramedic or physician a unique, portable, and battery-operated laser capability." The portable laser is a "completely self-contained laser package that fits inside a beltpack." (See Illustration 49). It requires "two 2-volt batteries to operate the laser and one 9-volt battery to power the electronics." It measures 7" by 3" by 2.5". It can operate continuously for 20 minutes at a time. The tip of the instrument is a "variable focus lens" at the tip of a flexible, fiber-optic cable that "provides very intense power density."

The device is "able to cut like a scalpel, as well as coagulate bleeding, and close wounds." It may be used by "special operations personnel" and others. According to the Office of Public Affairs at Kirtland AFB, "The output wavelength, which ranges from visible red to the mid-infrared, can be designed to provide different tissue interactions "(my emphasis).[1]

And all of this, mind you, is the size of a transistor radio, and is powered by batteries of the sort you can buy in line at the supermarket. So much for esoteric, "alien" medical technology.

How To Perform a "Typical" Cattle Mutilation

Permit me to present a hypothetical, "earthly" modus operandi for a cattle mutilation.

A dark, unmarked helicopter lifts off from Kirtland Air

Force Base. Inside the helicopter is a "special operations" team outfitted with a tranquilizer dart gun and surgical laser beltpacks. They fly for a couple of hours to an isolated ranch somewhere in a sparsely populated rural area (there are many areas of the rural West where the population density is less than one person per square mile). They land and shoot a cow with the dart gun. The tranquilizer immobilizes the animal so it cannot flee. They capture the animal, kill it and hoist it aboard the helicopter. On board they cut up the animal with the surgical lasers, removing the body parts they want to keep. They may even drain the blood for analysis (see Chapter 7 for a discussion of the types of material that the EPA is interested in for its nuclear contamination tissue sampling program). Then they unobtrusively lower the carcass to the ground from the helicopter, without landing.

Later, the carcass is discovered. There are no footprints or signs of struggle because the cow was picked up at a different place from where its carcass was found; its carcass was subsequently lowered to the ground on a sling, or rolled out the door after being slaughtered, without the helicopter touching down, or the crew leaving the craft.

The wounds on the carcass appear to be made with some type of surgical laser because, in fact, they were made with surgical lasers — surgical lasers carried on the beltpacks of a United States military special operations team. There is no blood around the carcass because the surgical lasers can coagulate bleeding and close wounds. There is no blood inside the carcass because it has been drained out for a tissue sampling project.

Ranchers and others in the area report seeing mysterious helicopters in the vicinity of the cattle mutilation, because the military mutilation teams travel in dark, unmarked helicopters.

So there you have a hypothetical cattle mutilation with all the classic details asociated with an "alien" cattle mutilation -- but plausibly explained as a covert human

operation using technology available now. And it is entirely possible the military has had this portable, surgical laser for years, since the military "black budget" world of special operations routinely conceals its activities from the public as a matter of policy, usually on grounds of "national security".

Why Do a Cattle Mutilation?

Now for the hypothetical "why" of it all.

One possibility is that there is some kind of covert environmental monitoring program going on, one like the Environmental Protection Agency (EPA) program discussed in Chapter 7. Cows are large mammals that are found everywhere that people are found, and they occupy a lower rung on the food chain than most humans, since bovines are herbivores. This means that they would more quickly absorb radioactive or chemical environmental contaminants than would most humans.

Perhaps the problems with our environment are far more serious than we have been told and a massive, covert monitoring program is under way. If this is the case, other government agencies could be involved, such as the EPA and the Department of Energy (See Chapter 7).

But why the emphasis on cattle? Is there some specific reason for singling them out? Must bovine tissues be obtained for some particular purpose, perhaps involving biological or genetic engineering? And if this is the case, what is the nature of the research and why and by whom is it being carried out?

Given the stealthy nature of the mutilations, these are tremendously difficult questions to answer. It may be, after all, that there is some sort of bizarre "alien" or extraterrestrial activity associated with the phenomenon.

But in light of the circumstantial evidence associated with many of the mutilations, such as unmarked helicopters and laser-like, surgical incisions, we would do well

not to turn a totally blind eye to possible culprits closer to home. It is not lost on me, for example, that many of the cattle mutilations have been located in New Mexico and southern Colorado, not far at all by air from Kirtland Air Force Base.

And there are plenty of dark helicopters at Kirtland.

And we now know that laser scientists at Kirtland Air Force Base have developed portable, surgical lasers that can fit in a beltpack.

Coincidence?

I wonder.

Afterword

LAST WORDS ON UNDERGROUND BASES, TUNNELS AND EXOTIC TUNNELING MACHINES

Based on the evidence in this book, it is absolutely certain that there are underground bases that have been secretly constructed in the United States in recent decades.

Who would be most likely to build bases of this kind? Any of the major agencies of the Pentagon would be capable of constructing deep underground facilities. Indeed, I have presented documentation generated by or pertaining to the Departments of the Army, Air Force and Navy and the Defense Nuclear Agency that indicate their interest, or direct involvement, in underground facilities. In my view it is likely that other Pentagon agencies and departments have similar interests, capabilities, and involvement.

Any reader of this book ought to come away with at least this one, basic understanding: the Pentagon is definitely heavily involved in and interested in underground facilities. There is no doubt about that.

A number of other non-military agencies are involved as well. The Department of Energy (DOE), the Federal Emergency Management Agency (FEMA), the National Security Agency (NSA), the Colorado School of Mines, and the Federal Reserve are some of the known underground players.

And there are the Fortune 500 companies that have

underground facilities. AT&T has a number of sophisticated underground centers. Northrop, Lockheed and McDonnell Douglas have hi-tech underground centers in California. Standard Oil at one time had a command post deep underground in New York state. There may be others operated by other companies.

Where secret tunnel systems and exotic tunneling machines are concerned the evidence is less conclusive. There are extensive Pentagon plans for a hundreds-of-miles-long tunnel network, thousands of feet underground in the desert Southwest (or somewhere). There are even contracts with the Air Force's Ballistic Missile Office that indirectly indicate that this tunnel system, or perhaps part of it, may have been built. But the evidence is fragmentary and circumstantial, and comes far from definitively proving that there is a secret military tunnel system. I have taken a wait-and-see attitude. The documentation is interesting, but in the final analysis plans, contracts and documents are not the same thing as real tunnels.

So, absent hard proof, the information presented in this book merely demonstrates a very strong military interest in building, even the intent to build, a huge, deep underground tunnel system. Were the tunnels built? Or are they being built right now? The short answer is: I do not know. If you do know, send me documentation, and if it's convincing, I'll publish it.

And then there are the plans for the Department of Transportation's deep underground tunnel system in the Northeast, linking major metro areas between Washington, DC and Boston, Massachusetts. Have miners in "moon suits" been operating flame-jet tunnelers to make a tunnel system there, or elsewhere? Planning documents for such a project do exist. But here again, as with the Pentagon plans, documents are one thing, and actual tunnels quite

another.

Of course, for your garden variety secret tunnel system there is a choice of tunneling machines. There is always the dependable, conventional, electrically powered, mechanical TBM. And there are lots of these digging away around the world, making all sorts of tunnels for subways, highways and water works.

Then there are the plans for nuclear subterrenes, electron beam excavators, and flame-jet tunnelers. Do these exotic tunneling machines exist? They might; they might not. But if they do you can bet on one thing: they are being used covertly, in considerable secrecy, because I have examined thousands of pages of recent tunneling literature and there is no mention of their use anywhere. At the same time, I did uncover plans for these strange machines generated by the military-industrial complex. So, I do not summarily dismiss the possibility that these machines may be in secret use. There the matter rests for now.

Finally, there are out-of-this-world plans for "subselenean" or lunar tunnelers. In design these machines have many similarities to their earthly, nuclear subterrene or TBM counterparts. If I am at a loss to draw many firm conclusions about secret tunnels and exotic tunneling machines here on Earth, I am at even more of a loss when it comes to deciding about tunneling activity on the Moon.

There are rumors in some of the wilder corners of UFOlogy about a secret space program and covert, manned, lunar bases. Here again: I suppose anything is possible, but I have yet to see any kind of direct proof that this secret space program exists, or that there are secret bases on the Moon. Rumors are not the same thing as solid evidence, and researchers must be careful to remember that simple truth.

So there you have it.

This book constitutes just about as representative a treatment of the subject of underground bases and tunneling activity as is presently possible from reading information that is publicly available in a moderately good research library.

I have no contacts in the intelligence community; I have had no access to classified material. Almost all of the material in this book comes from the public record. Anyone who is willing to do methodical investigation in a good research library and dig hard can find much the same kind of information as that presented here.

Truth to tell, there is certainly interesting information yet to be discovered on all of these topics. To find that information, you have to creatively examine electronic databases, periodical and newspaper indexes, federal document and technical document indexes, patent indexes, card catalogues, and every other kind of index that you can think of. And then you track down the document and article citations that you find.

Serious research is tedious and time consuming. But it can yield results if you stick with it.

A Final Word

Our First Amendment right to freedom of speech and freedom of the press is only as strong as we make it. We have the constitutional right to go into libraries and databases, and to read and then to write about what the government and major corporations are doing. I am exercising this right. I hope that others who read this book will do the same.

I welcome information and plans, diagrams, photos, videos, and all forms of evidence from readers about any

and all underground tunnels, tunneling machines and underground bases -- or strange "UFO" or "extraterrestrial" technology. The more detailed and specific the information is, the more useful it will be. If you desire anonymity, either send me the material anonymously or make your desire for anonymity crystal clear when you communicate with me.

All materials and information become my property, to use or not as I see fit, without further obligation or compensation to the sender.

You may send information directly to me:

Richard Sauder
c/o Adventures Unlimited
Box 74
Kempton, IL 60946 USA

Footnotes

FOOTNOTES

Chapter One -- Oh Yes, They're Real!

1. Lloyd A. Duscha, "Underground Facilities for Defense - Experience and Lessons," in Tunneling and Undergound Transport: Future Developments in Technology. Economics and Policy, ed. F.P. Davidson (New York: Elsevier Science Publishing Company, Inc., 1987), pp. 109-113.
2. Albert D. Parker, Planning and Estimating Underground Construction. (New York: McGraw Hill Book Company, 1970), pp. 140,142.
3. U.S. Dept. of Defense, U.S. Army Corps of Engineers, Construction Engineering Research Laboratory, Literature Survey of Underground Construction Methods for Application to Hardened Facilities. Report No. CERL TR M-85/11 (April 1985), pp. 2, 7, 34 and 36.
4. Lt Col. J.A Goshorn, "Should We Go Underground," Armed Forces Chemical Journal 3 (July 1949), p. 25.
5. Duncan Campbell, "War Games," New Statesman & Society 2 (26 May 1989), p. 11.
6. "Underground Missile Plant To Be Built Near Redstone," Missiles and Rockets. 2 (May 1957), p. 43.
7. "Underground Factory in the Works?," Missiles and Rockets. 2 (Sep 1957), pp. 52-53.
8. "SAGE Goes Undergound Near Dobbins," Air Force Times. 20 (7 Nov 1959), p. 24.
9. Paul R. Nyquist, PE and Andre M. Ranford, PE, "Diesel Power for Command and Control Centers," Air Force Civil Engineer 5 (February 1964), p. 30.
10. U.S. Department of Defense, Department of the Army, Office of the Chief of Engineers, Utilization of Nuclear Power Plants in Underground Installations. Engineer Manual No. EM 1110-345-950 (15 April 1963), pp. 1-2, 6 and 28-29.
11. Nyquist and Ranford, p. 33.

Chapter Two -- The Military Underground: Air Force, Army and Navy

1. J.J. O'Sullivan, ed., Protective Construction in a Nuclear Age. Vol. 1. Proceedings of the Second Protective Construction Symposium. 24-26 March. 1959 (New York: The MacMillan Company, 1961), pp. vi, 1-3. There is also a second volume, with the same editor and title.
2. S.M. Genensky and R.L Loofbourow, Geological Covering Materials for Deep Underground Installations. U.S. Air Force Project Rand Research Memorandum RM-2617. Research sponsored by the U.S. Air Force under contract AF 49(638)-700, (Santa Monica, CA: The RAND Corp., 4 August 1960), p. 4.
3. Ibid, pp. 20-30.
4. Ibid, pp. 33-37.
5. Ibid, various pages throughout the document. There appears to be a minor geographical error in this report It places the Vermilion Cliffs in Mohave County; however, the Vermilion Cliffs actually are in Coconino County, near the Kaibab National Forest.
6. David H. Morrissey, "Underground Depot to Replace Manzano Nuclear

Storage Site," Albuquerque Journal. 12 Sep 1989, pp. 1A and 3A.
7. Ibid; and John Fleck, "Bombs Away," Albuquerque Journal. 2 August 1992, pp. 1A and 6A.
8. Undated article, of uncertain origin, by Earl Zimmerman, entitled "LASL's Unusual Underground Lab," received from the Albuqerque Office of the Department of Energy, as an enclosure in a letter to the author.
9. EBE is an acronym used frequently in UFOlogy to refer to "Extraterrestrial Biological Entity". In plain English an EBE is an alien being, or an extraterrestrial being. The EBEs remored to be held at Los Alamos in the past were allegedly of the "Little Grey" type. I am unable to verify this allegation of EBEs being held at Los Alamos.
10. Harry V. Martin, various articles in an information packet obtained from the Napa Sentinel. ©1992. The Napa Sentinel is a weekly newspaper. Interested readers may contact the Sentinel at 925 Lincoln Ave., Napa, CA 94558 (707)257-6272.
11. U.S. Department of Defense, Department of the Army, Army Corps of Engineers, Design of Underground Installations in Rock: General Planning Considerations. Manual No. EM 1110-345-431 (1 January 1961), Page 7. The one manual in this series which I do not quote from is entitled Design of Underground Installations in Rock: Penetration and Explosion Effects. Manual No. EM-1110-345-434 (31 July 1961). It is also published by the U.S. Army Corps of Engineers.
12. _____ , Heating and Air Conditioning of Underground Installations. Manual No. EM 1110-345-450 (30 Nov. 1959), pp. 5-7, and 83-85.
13. _____ , Design of Underground Installations: Protective Features and Utilities. Manual No. EM 1110-345-435 (1 July 1961), pp. 5-6, 11-25, 62-74.
14. _____ , Design of Underground Installations in Rock: Space Layouts and Excavation Methods. Manual No. EM 1110-345-433 (1 April 1961), pp. 5, 8 and 9-16.
15. U.S. Department of Defense, Department of the Army, U.S. Army Corps of Engineers, Army Engineer Waterways Experiment Station, Feasibility of Constructing Large Underground Cavities: Background. Site Selection, and Summary. Technical Report No. 3-648, Vol. 1, July 1964, Sponsored by Advanced Research Projects Agency, ARPA Order No. 260-62, Amendment No. 1, pp. vii-viii, 26 and 31. (The U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi contracted out the study to the Colorado School of Mines Research Foundation, in Golden, Colorado and to Jacobs Associates Construction Engineers of San Francisco, California.)
16. Ibid, p. 31.
17. _____ , Feasibility of Constructing Large Underground Cavities: Report On Cost and Constructabilitv. Technical Report No. 3-648, Vol. III, June 1964, Sponsored by Advanced Research Projects Agency, ARPA Order No. 260-62, Amendment No. 1, p. 21.
18. _____ , Feasibility of Constructing Large Underground Cavities: Background. Site Selection, and Summary. Vol. 1, pp. 35-66.
19. _____ , Feasibility of Constructing Large Underground Cavities: Report on Cost and Constructabilitv. Vol. III, various pages.
20. William M. Arkin and Richard W. Fieldhouse, Nuclear Battlefields: Global Links in the Arms Race. (Cambridge, Mass.: Ballinger Publishing Co., 1985), p. 211.
21. R. Hibbard, L. Pietrzak and S. Rubens, Subsurface Deployment of Naval Facilities. Report sponsored by Naval Facilities Engineering Command, contract no. N00025-72-C-0009, Federal Document No. AD-762 838, and the following number

of unknown significance CR-2-318, December 1972.
22. James Bamford, The Puzzle Palace: A Report on America's Most Secret Agency (Houghton Mifflin Co., 1982; reprint ed., NY, NY: Penguin Books, 1983), p. 221.

Chapter Three -- The Ultimate War Rooms

1. Steven Emerson, "America's Doomsday Project," U.S. News & World Report. 7 Aug 1989, pp. 26-31.
2. Douglas Heuck, "'Underground Pentagon' Quietly Awaits Armageddon," The Albuquerque Tribune. 25 November 1991, pp. ID and 2D; Richard H.P. Sia, "As Cold War Wanes, Pentagon's Pennsylvania Fortress Lifts Its Alert," The Baltimore Sun. 20 April 1992, p. 1A and 10A; and William M. Arkin, Joshua M. Handler, Julia A. Morrissey and Jacquelyn M. Walsh, Encyclopedia of the U.S. Military. (New York: Harper and Row, Ballinger Division, 1990) p. 63.
3. Ted Gup, 'The Doomsday Blueprints," Time (10 Aug 1992), p. 37.
4. John Guthrie, "Underground Command Posts," International Combat Arms. 5 (May 1987), p. 19.
5. Arkin and Fieldhouse, Nuclear Batdefields. p. 181; William R. Evinger, ed., Directory of Military Bases in the U.S.. (Phoenix, AZ: Oryx Press, 1991), p. 33; and Arkin et al, Encyclopedia of the U.S. Military, pp. 482-483.
6. John M. Norvell, "The Rock'-NORAD COC," The Military Engineer. No. 367 (Sep-Oct 1963), pp. 309-311; and Guthrie, "Underground Command Posts," p. 19.
7. LB. Leonberger, "Under the Pre-Cambrian Shield," Airman. 14 (March 1970), pp. 11-12; K.G. Roberts, "Air Defence Goes Underground," The Roundel. 15 (Sep 1963), pp. 8-13; and "NORAD at North Bay: Underground Center a Joint Effort," Air Force Times. 29 (12 Feb 1969), p. 27.
8. Ted Gup, "Doomsday Hideaway," Time. 9 Dec 1991, pp. 26-29; and Richard P. Pollock, 'The Mysterious Mountain," The Progressive. March 1976, pp. 12-16.
9. Richard P. Pollock, 'The Mysterious Mountain, The Progressive. March 1976, pp. 12-16; and Ford Rowan, Technospies: The Secret Network That Spies on You -- and You (New York: G.P. Putnam's Sons, 1978), pp. 25-43.
10. Ibid; and Arkin, Handler, Morissey and Walsh, Encyclopedia of the U.S. Military, pp. 177-179, 270-272.
11. U.S. Congress, Senate, Committee on the Judiciary and Committee on Commerce, Surveillance Technology. Joint Hearings Before Subcommittees of the Senate Committees on the Judiciary and Commerce. 94th Cong., 1st Session, 1975, pp. 63-100.
12. Jack Anderson and Dale Van Atta, 'Top Secret Hide-Outs Also Mask Flaws," The Washington Post. 29 August 1991, 23B.

13. Arkin and Fieldhouse, Nuclear Batdefields. p. 210.
14. Ted Gup, 'The Ultimate Congressional Hideaway," The Washington Post Magazine. 31 May 1992, p. 15; and Rowan, Technospies. pp. 34-35.
15. Rowan, Technospies. p. 35.
16. Ted Gup, 'The Doomsday Blueprints," Time (10 August 1992), p. 38.
17. Arkin and Fieldhouse, Nuclear Battlefields, p. 193.
18. Ibid; and Arkin, Handler, Morissey and Walsh, Encyclopedia of the U.S. Military, p. 273.
19. Robert D. Hershey, Jr., "A Bunker Just For Lawmakers Who Now May Run For Cover," The New York Times. 31 May 1992, pp. 1 and 20; Tom Webb, 'The Last Resort," Albuquerque Journal. 30 May 1992, pp. 1A and 9A; and Ted Gup,

"The Ultimate Congressional Hideaway," The Washington Post Magazine. 31 May 1992, pp. 10-15, 24-27.
20. Arkin, Handler, Morrisey and Walsh, Encyclopedia of the U.S. Military, p. 273.
21. Letter to the author, dated 2 March 1993, from William F.W. Jones, Deputy Associate Director, National Preparedness Directorate, Federal Emergency Management Agency.
22. H.R. Pratt and S.J. Green, A Geology Compendium of the Continental United States - With Application to Deep-Based Systems. Report prepared by Terra Tek, Inc., Salt Lake City, Utah for the Defense Nuclear Agency. Federal Document No. DNA 3874F, 15 November 1975.
23. Oliver North, Under Fire: An American Story (New York: Harper Collins, 1991), pp. 164-166.
24. Tim Weiner, "Pentagon Book For Doomsday Is to Be Closed," New York Times. 18 April 1994.
25. "No Comment," The Progressive. 56 (August 1992), p. 11.

Chapter Four -- More Underground Facilities

1. "Logistics Goes Underground," Army Logistician. 6 (July-Aug 1974), pp. 32-33.
2. Ray Vicker, "Going Underground," The Wall Street Journal. 17 June 1981, p. 56.
3. Bamford, Puzzle Palace, p. 133.
4. The information on the plans for Yucca Mountain, Nevada comes from DIALOG FILE 194, an electronic database that catalogues announcements that appear in the Commerce Business Daily. Commerce Business Daily is a list of federal contract announcements and bid solicitations published every working day by the U.S. Department of Commerce. The announcements referenced here were published on 10 May 1991; 10 Feb 1992; 11 Sep 1992; and 22 Oct 1992. Responses were solicited by: Reynolds Electrical and Engineering Co. Inc., Yucca Mountain Project, PO Box 98521, Mail Stop 408, Las Vegas, NV 89193-8521.
5. Michael Martin Nieto, "Physics at the Proposed National Underground Science Facility," in Proceedings of the XIV International Symposium on Multiparticle Dynamics. Granlibakken. Lake Tahoe. California. 22-27 June 1983. ed. P. Yager and J.F. Gunion, scientific secretary K. Sparks (Singapore: World Scientific Publishing Co Pte Ltd., 1984), 1107-1119.
6. Ted Gup, "The Doomsday Blueprints," Time. 140 (10 August 1992), p. 38.
7. The material on the Northrop, McDonnell Douglas and Lockheed facilities, and associated strange goings-on, can be found in articles in the Nov 1992 issue of HUFON REPORT: The Newsletter of the Houston UFO Network. Inc.. from PO Box 942, Bellaire, TX 77402 (713)850-1352.
8. Ray Vicker, "Going Underground," The Wall Street Journal. 17 June 1981, p. 56.
9. Per author's personal conversation with former AT&T emplyee.
10. Research Program Plan for Meeting Tomorrow's Needs in Tunneling and Excavation: Final Report. Federal Document Nos. NSF-RA-T-74-087 or PB 242 777, Contract C-841. Study performed by Bechtel Corporation for the National Science Foundation, Research Applied to National Needs (RANN), March 1974, p. 53.
11. "Demand Forecast of Underground Construction and Mining in the United States," Subcommittee on Demand Forecasting, U.S. National Committee on

Tunneling Technology, Assembly of Engineering, National Research Council, Federal Document number NRC/AE/TT-81-1 (Washington, D.C.: National Academy Press, 1981), p. 20.

Chapter Five ~ The Mother of All Underground Tunnels?

1. U.S. National Committee on Tunneling Technology, U.S. National Committee on Tunneling Technology Report for 1977. NTIS, PB-300 527; also might be found under Federal Technical Document No. NSF/RA-780668. As of 1983 the address of the committee was: U.S. National Committee on Tunneling Technology, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418.
2. U.S. National Committee on Tunneling Technology, Report for 1981 and 1982. U.S. National Committee on Tunneling Technology (Washington, D.C.: National Academy Press, 1983).
3. W.G. Harris and H. Oman, "Chlorine as an Oxidizer for Fuel Cells and Its Containment," Boeing Aerospace Company report, in 19th Intersocietv Energy Conversion Engineering Conference. Vol. 2. "Advanced Energy Systems -- Their Role In Our Future." (San Francisco, CA: American Nuclear Society, 19-24 August 1984), pp. 810-814.
4. Design and Construction of Deep Underground Basing Facilities for Strategic Missiles. Vol. 1. Evaluation of Technical Issues. Report of a Workshop Conducted by the U.S. National Committee on Tunneling Technology, Commission on Engineering and Technical Systems, National Research Council, federal technical document no. NRC/CETS/TT-82-1 (Washington, D.C.: National Academy Press, 1982). This report is 68 pages long and worth reading in its entirety. I have only culled out some highlights.
5. George B. Clark, Levent Ozdemir and Fun-Den Wang, Tunnel Boring Machine Technology for a Deeply Based Missile System. Volume II. State-of-the-Art Review. report prepared by Colorado School of Mines, Golden, Colorado 80401, for the Air Force Weapons Laboratory at Kirtland Air Force Base, New Mexico 87117, Federal Technical Document No. AFWL-TR-79-120, Vol. II, August 1980. Also, George B. Clark, Levent Ozdemir and Fun-Den Wang, Tunnel Boring Machine Technology for a Deeply Based Missile System. Volume I. Part 1. Application Feasibility. Report prepared by Colorado School of Mines, Golden, Colorado, for the Air Force Weapons Laboratory at Kirtland Air Force Base, New Mexico 87117, Federal Technical Document No. AFWL-TR-79-120, Vol. 1, Part 1, August 1980.
6. Richard Halloran, "Air Force Seeks Missile Base Deep Underground for 1990s," The New York Times. 3 Oct 1984, pp. Al and A23.
7. "A Subterranean Air Force?" Asian Defence Journal. April 1985, p. 97.
8. John J. Cipar, Explosion-Induced Ground Motion Within a Deep Base. Report prepared for Air Force Geophysics Laboratory, Hanscom Air Force Base, Massachusetts 01731, Federal Technical Document No. AFGL-TR-85-0339. Environmental Research Papers No. 940, 8 Nov 1985.
9. "ICBM Deep Basing Construction Planning Study," paper presented by Patrick D. Lindsey of the U.S. Army Corps of Engineers, Omaha District, Nebraska, in 26th U.S. Symposium on Rock Mechanics/Rapid City. SD. 26-28 June 1985, pp. 1189-1196.
10. U.S. National Committee on Tunneling Technology and U.S. National Committee for Rock Mechanics, "Advances in Technology for the Construction of Deep-Underground Facilities," Tunnelling and Underground Space Technology 3 (1988), pp. 25-44.

11. Department of Defense News Release, 7 November 1985, vol. 85, no. 652, p. 2. This reference was accessed through DIALOG FILE 80. DIALOG is a computer data base.
12. Department of Defense News Release, 6 December 1985, vol. 85, no. 700, p. 1. Reference accessed through DIALOG FILE 80.
13. Department of Defense News Release, 24 April 1986, vol. 86, no. 180, p. 2. Reference accessed through DIALOG FILE 80.
14. Department of Defense News Release, 19 August 1987, vol. 87, no. 416, p. 3. Reference accessed through DIALOG FILE 80.
15. Department of Defense News Release, 29 July 1985, vol. 85, no. 450, p. 2. Reference accessed through DIALOG FILE 80.
16. Though this makes little sense, since both the French and the Japanese have high speed, inter-city rail systems, and in both cases the systems are almost completely on the surface. In neither case have the designers created an extensive, underground tunnel network as set forth in the United States Department of Transportation (DOT) plans. Could the DOT plans really be for a secret tunnel system, published under the guise of an inter-city, mass transit project that actually never was intended for public use?
17. High Speed Ground Transportation Tunnel Design and Cost Data. Report prepared by HARZA Engineering Company, Chicago under subcontract W0356-SC, under prime contract C-353-66 (NEG), for the Office of High Speed Ground Transportation, United States Department of Transportation, Federal Document No. PB 178-201, (also carries following number of unknown significance on the title page: 06818-W454-R0-11), document dated March 1968.

Chapter Six — Tunnelling Machines

1. J. George Thon, "Tunnel-Boring Machines," in Tunnel Engineering Handbook, ed. John O. Bickel and T.R. Kuesel (New York: Van Nostrand Reinhold Co., 1982), pp. 235-278.
2. Ibid, pp. 244-247.
3. Underground Structures. Design and Construction, ed. R.S. Sinha (New York: Elsevier Science Publishing Co., Inc., 1991), 293-299.
4. Research Program Plan for Meeting Tomorrow's Needs in Tunneling and Excavation -- Final Report. Report prepared by Bechtel Corporation for the National Science Foundation, Research Applied to National Needs (RANN), federal technical document no. NSF-RA-T-74-087, or Federal No. PB 242 777, March 1974, p. 224.
5. "Research and Development," Government Executive 3 (Jan 1971), pp. 22-23.
6. J. George Thon, 'Tunnel-Boring Machines," in Tunnel Engineering Handbook. pp. 275-276.

7. Feasibility of Flame-Jet Tunneling. Vol. I - Summary Report. Report by United Aircraft Research Laboratories, United Aircraft Corporation, East Hartford, Connecticut, for U.S. Department of Transportation, Office of High Speed Ground Transportation, Federal Document No. G-910560-10, or PB-178198, May 1968.
8. Feasibility of Flame-Jet Tunneling. Vol. II - Systems Analysis and Experimental Investigations. Report by United Aircraft Research Laboratories and Browning Engineering Corp., for U.S. Dept. of Transportation, Office of High Speed Ground Transportation, Federal Document No. G-910560-10, or PB-178199, May 1968.
9. R.T. Avery, D. Keefe, T.L Brekke and I. Finnie, "Hard Rock Tunneling Using

Pulsed Electron Beams," in Accelerator Division Annual Reports. 1 July 1972 -- 31 December 1974. LBL-3835, UC-28 Particle Accelerators, TID-4500-R62, Lawrence Berkeley Laboratory, University of California, Berkeley, CA, pp. 29-32.
10. US. Patent No. 3,693,731, 26 Sep 1972.
11. US. Patent No. 3,881,777, 6 May 1975.
12. US. Patent No. 3,885,832, 27 May 1975.
13. J.H. Altseimer, Systems and Cost Analysis for a Nuclear Subterrene Tunneling Machine: A Preliminary Study. Federal Technical Document No. LA-5354-MS, Informal Report UC-38, Sep 1973, p. 1.
14. John D. Bledsoe, J. Ernest Hill and Richard F. Coon, Cost Comparison Between Subterrene and Current Tunneling Methods. Appendix A, Baseline Cost Analyses, prepared for National Science Foundation, by A.A. Mathews, Inc., Rockville, MD, Federal Document No. NSF-RA-T-75-001A, also No. PB 244 482, May 1975. Also John D. Bledsoe, J. Ernest Hill and Richard F. Coon, Cost Comparison Between Subterrene and Current Tunneling Methods. Appendix B. Subterrene Cost Analyses, prepared for National Science Foundation, by AA Mathews, Inc., Rockville, MD, Federal Document No. NSF-RA-T-75-001B, PB 244 483, May 1975; and John D. Bledsoe, J. Ernest Hill and Richard F. Coon, Cost Comparison Between Subterrene and Current Tunneling Methods. Final Report. prepared for National Science Foundation, by AA Mathews, Inc., Rockville, MD, Federal Document No. NSF-RA-T-75-001, May 1975.
15. Joseph W. Neudecker, Jr., James D. Blacic and John C. Rowley, Subselene: A Nuclear Powered Melt Tunneling Concept for High-Speed Lunar Subsurface Transportation Tunnels, submitted to Symposium '86, Atlantic City, NJ, 22-24 Sep 1986, prepared by Los Alamos National Laboratory, Los Alamos, NM 87545, Federal Document No. LA-UR-86-2897, December 1986.
16. Christopher S. Allen, David W. Cooper, David Davila Jr., Christopher S. Mahendra and Michael A. Tagaras, Proposal for a Lunar Tunnel-Boring Machine. report presented to Prof. Stan Lowy, Dept. of Aerospace Engineering, Texas A8cM Univ., research funded by NASA/USRA Grant, 5 May 1988, pp. ii and 15.

17. Ibid, p. 49.
18. Bill Engblom, Eric Graham, Jeevan Perera, Alan Strahan and Ted Ro, Subselenean Tunneler Melting Head Design: A Preliminary Study, by Texas A&M Aerospace Engineering, College Station, TX 77840, Federal Technical Document No. N89-17058, or NASA-CR-184750, May 1988.

Chapter Seven - Nuclear Testing, The EPA, Abductions

1. All information and illustrations cited or used in this article that pertain to the government program that monitors humans and animals are from the following document: U.S. Congress, Office of Technology Assessment, The Containment of Underground Nuclear Explosions. OTA-ISC-414 (Washington, DC: U.S. Government Printing Office, October, 1989), pp. 65-80.

Chapter Eight - Abductions, Needles and Implants

1. Texas Instruments, Inc. and the huge General Motors subsidiary, Hughes Aircraft Co., are two of the companies involved in this field. There are a number of others. 'Texas Instruments Enters Automatic Identification Market," Feedstuffs 63 (1 April 1991), p. 18; and "TI Sets Volume Transponder Production for IDs," Electronic News 38 (21 September 1992), p. 16.

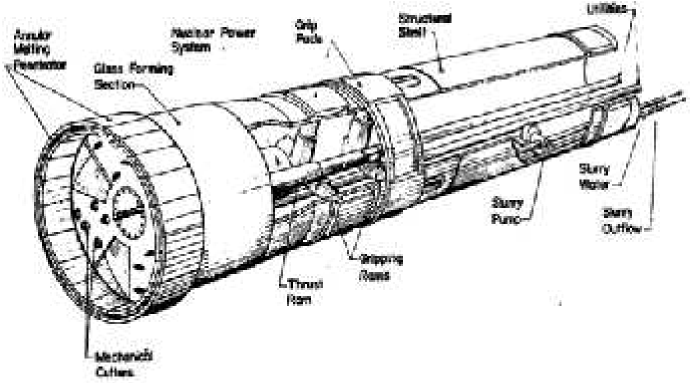
2. A General Motors subsidiary, Hughes Aircraft Co., is co-assignee for one of the patents (United States Patent 5,211,129, dated 18 May 1993). Hughes Aircraft subsequently formed its own electronic identification company, known as Hughes ID. "Hughes Enters ID Market," Microwaves & RF 31 (January 1992), p. 21.
3. United States Patent 5,211,129, granted 18 May 1993.
4. United States Patent 5,250,026 granted 5 October 1993.
5. United States Patents: 4,730,188 granted 8 March 1988; 5,041,826 granted 20 August 1991; and 5,166,676 granted 24 November 1992.
6. United States Patent 5,041,826, granted 20 August 1991.
7. I do not claim to know the ultimate reason(s) for the abductions. Given the bizarre nature of the phenomenon, though, I am prepared to believe that the underlying motivations may appear, in the ordinary perceptual framework of humanity, to be highly strange.
8. The fact that young children and older people who may be infertile are also abducted need not invalidate this hypothesis. Children with desirable traits may be targeted early on, perhaps because of a genetic heritage that is of interest to the abductors. And whether young or old, it may be that other bodily tissues, all of which contain the genetic material (DNA) of the abductee, can be used in place of sperm or ova.
9. I have no proof that there are functional, artificial wombs for human fetuses. For the sake of the hypothesis I am postulating that they may exist. But even if they don't, contemporary medical technology still admits both of artificial insemination using donor sperm and in vitro fertilization.

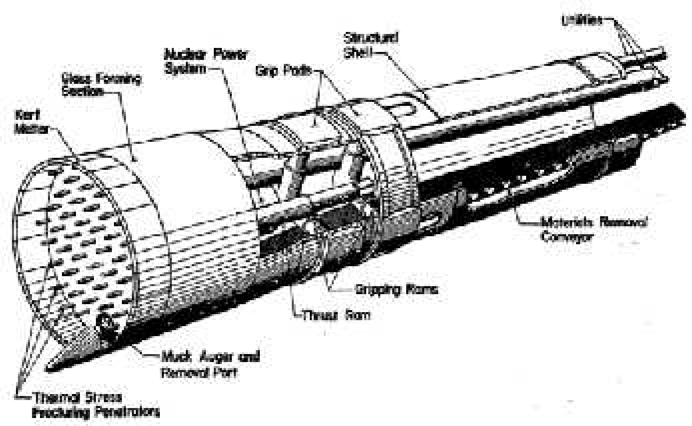
10. I am reminded of Charles Fort, who questioned whether this planet and the human race might not be someone's "property."
11. The metaphor of the hall of mirrors, and the idea that very human terrestrials (including the military), operating behind an intricate, technologically sophisticated web of deception and disinformation, may well be at work in the UFO/abduction phenomenon are mentioned in Jacques Vallee's excellent book Revelations: Alien Contact and Human Deception (New York: Ballantine Books, 1991). Martin Cannon, of Prevailing Winds Research has also advanced the idea of covert, human involvement in the abduction and implantation phenomena. More recently, Leah Haley has written of her experiences with joint military and "alien" abductions. Finally, I would ask readers to please note that my objective with the whole abduction/implant phenomenon is simply to present relevant facts, present a possible hypothesis that may shed some light on the subject, and thereby to stimulate a more informed discussion.

Chapter Nine - Is the U.S. Military Involved in "Alien" Cattle Mutilations?

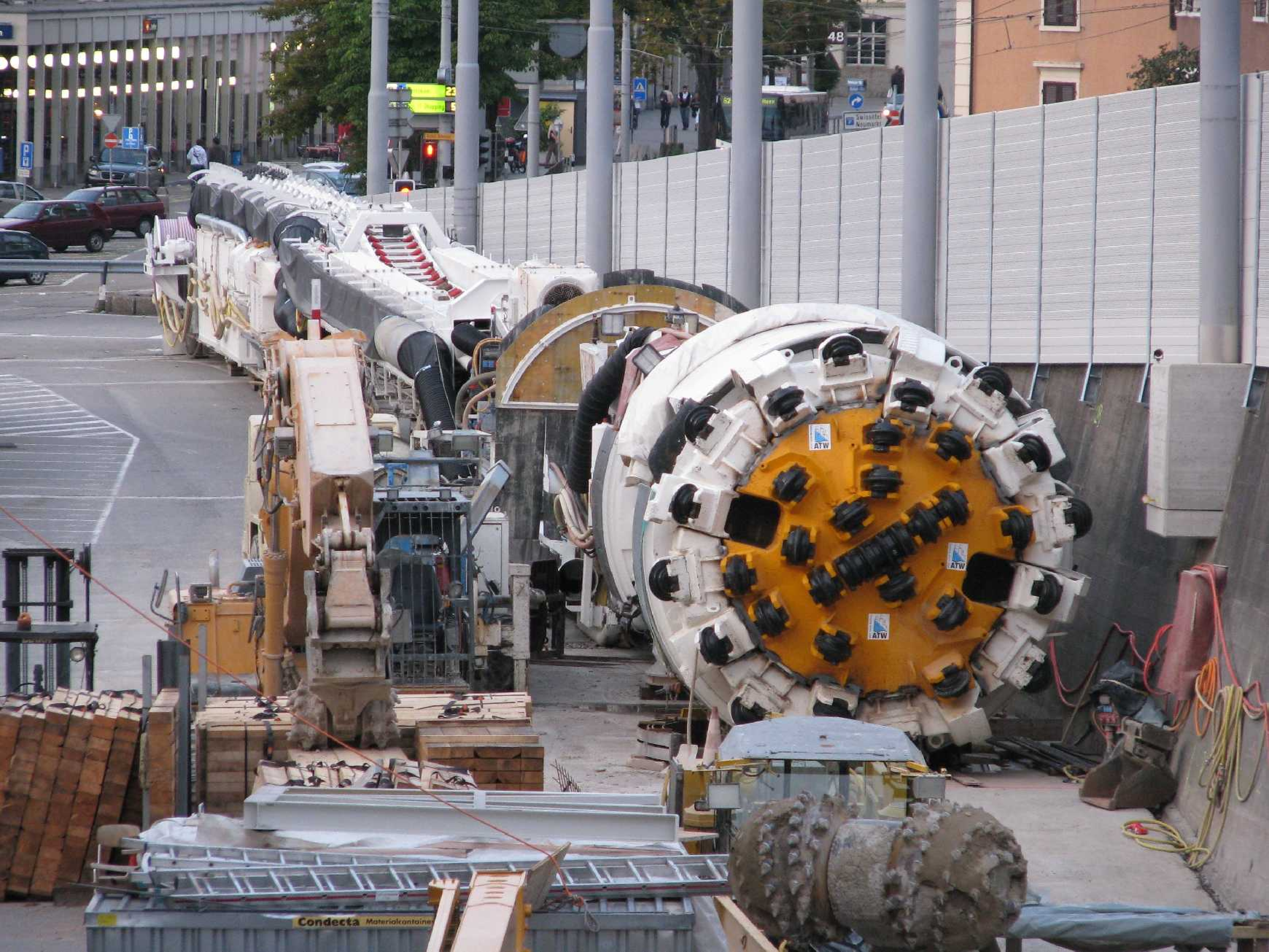
1. "Laser Medical Pac," Fact Sheet, Office of Public Affairs, Phillips Laboratory (505)-846-1911, 3550 Aberdeen Ave SE, Kirtland AFB, NM 87117-5776, January 1994.

LOS ALAMOS
TAL '90


Annular Melting Penetrator
Nuclear Power System
Glass Forming Section
Grip Pads
Structural Steel
Utilities
Slurry Water
Slurry Pump
Slurry Outflow
Gripping Rams
Thrust Ram
Mechanical Cutters


Utilities
Structural Shell
Nuclear Power System
Grip Pads
Glass Forming Section
Kerf Melter
Materials Removal Conveyor
Gripping Rams
Thrust Ram
Muck Auger and Removal Port
Thermal Stress Fracturing Penetrators


U.S AIR FORCE


48
ATW
ATW
ATW
Condecta